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A Primer on Integrating Resource Inventories

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A Primer on Integrating Resource Inventories

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Contents

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Introduction

Primer Objectives

To manage natural resources efficiently, decisionmakers need information on resources and their potential changes over time. Inventories provide that information. Inventories also are necessary to evaluate the interactions of demands and supply and cause/effect relationships among and within resource systems. Hence, inventories are prerequisites for sound program direction and effective management decisions throughout all resource systems, whether at the local, regional, national, or international level.

Most data are commonly obtained through resource-specific inventories. The resulting information may be incompatible, redundant, incomplete, or even contradictory beyond statistical margins of error when assembled for multiresource assessment purposes. The more diverse and independent the data sources are, the more complex becomes the problem of building resource assessments that are meaningful, valid, and efficient.

We seek integration and coordination to increase the effectiveness of our inventories, to minimize duplication and overlapping efforts, to enhance data sharing, and to better design inventories to meet emerging information needs (Peterson 1984).

Integration results in better data, coordinated land and resource planning activities, and reduced data collection and reporting efforts. Increased validity of data permits better decisionmaking and understanding of the consequences of the decisions (Lund 1979a).

The objective of this primer is to present a framework for integrating inventories so that we can:

- Achieve greater uniformity and standardization for comparing and combining the resource data obtained from different sources while leaving latitude for specialized information to meet local conditions.

- Improve the efficiency of inventory operations so that better, more reliable, and more useful information can be obtained at equal or lower costs.

- Intensify the cooperation and collaboration between inventory specialists and the users of the results so that pertinent information can be obtained.

The first section of this publication provides an introduction and background information. The second section describes the underlying principles necessary for achieving inventory integration. The third section discusses various needs, problems, and options and recommendations relative to the type of integration sought. The fourth section covers in detail how to plan, implement, and maintain an integrated system of inventories.

By applying the principles and techniques presented, the inventory specialist will be better able to design surveys that are more responsive to the needs of today's decisionmakers.

Background

The need for valid forest land and rangeland inventories has existed since the creation of the National Forest System in 1891. However, a detailed inventory of resources in the United States has not been required until recently. In 1974, the Forest and Rangeland Renewable Resources Planning Act (RPA) authorized the Secretary of Agriculture to make and maintain (among other things) a comprehensive inventory of the present and prospective conditions of and requirements for the renewable resources of the forest and rangelands of the United States. The objective of the Act is to maintain and report, on a continual basis, a comprehensive and appropriately detailed inventory and assessment of the resources of all forest and range lands.

In 1976, Congress passed the National Forest Management Act (NFMA) specifying that an interdisciplinary approach be used in land and resource management planning for the National Forest System. The NFMA requires that the inventories backing land and resource management plans be integrated so that relations between resources can be determined. The Federal Land Policy and Management Act of 1976 (FLPMA) and the Soil and Water Conservation Act of 1977 (RCA) provide similar requirements. These legislative acts share the following assignments:

- Preparation and maintenance of continuous natural resource inventories.

- Coordination and cooperation among resource agencies and organizations to avoid duplication of inventory and planning efforts.

- Determination of both current and potential changes in renewable natural resources.

- Determination of resource interactions and management alternatives.

- Submission of periodic assessment reports of the natural resources of the Nation (Rivers 1982).

As the legislation (RPA, FLPMA, and RCA) was implemented, problems surfaced between agencies. For example, dual reporting of statistics showed there was a reporting discrepancy of approximately 20 million hectares (50 million acres) of non-Federal forest land between the USDA Soil Conservation and the Forest Service (Van Hooser and Green 1981).

To avoid such contradictions and reduce duplication, an interagency group comprising the USDA Soil Conservation Service and Forest Service and the USDI Bureau of Land Management, Fish and Wildlife Service, and Geological Survey was formed in October 1978. The mission of the group was to develop mutually useful and common techniques for gathering and exchanging information. The USDA Forest Service Resource Evaluation Techniques (RET) Program (formed in 1976) became an integral part of the interagency group.

In 1979, Federal research began to respond to the legislation and recommendations of the interagency group. Four research work units were formed within the USDA RET Research and Development Program dealing with national assessments, classification systems, inventory techniques, and remote sensing. Scientists from the Forest Service, Soil Conservation Service, Bureau of Land Management, and Fish and Wildlife Service were assigned to work within the program to assure compatibility of systems developed.

The mission of the RET program was to maintain and improve capabilities for national inventories and analysis of renewable resources. One problem assigned to the RET Inventory and Remote Sensing Unit was to conceptualize a framework for a multiresource inventory system for timber and range resources. A national conference (Lund and others 1978), a literature review (Lund and McNutt 1979), and the initial work of the RET units showed that working solely on multiresource inventory techniques would not solve the problems facing the various Federal agencies. Multilocation, multilevel, and temporal integration also had to be considered (Lund and Myers 1982). Consequently the RET inventory task was broadened to develop a framework for evaluating and efficiently integrating data from diverse sources.

In July 1981, a draft of the framework was prepared by the Inventory and Remote Sensing Research Work Units and the Statistical Research and Support Group and submitted to the Interagency Group for review and comment.

It has been updated and expanded to incorporate results of three significant conferences—one on in-place resource inventories (Brann, House, and Lund 1982), one on renewable resources for monitoring changes and trends (Bell and Atterbury 1983), and a Forest Service Workshop on inventory integration (Schlatterer and Lund 1984).

Definitions

An understanding of the following terms will be helpful in using this primer.

Accuracy: The closeness of an observation to the quantity intended to be observed.

Aggregable data: Two or more mutually exclusive data sets using the same standards and definitions for purposes of combining.

Bias: The difference between the true value and an estimate of the true value.

Capability: The potential of an area to produce resources, supply goods and services, and allow resource uses under an assumed set of management practices and at given level of management intensity.

Classification: The systematic grouping of entities into categories based upon shared characteristics.

Coefficient: A constant used in an algebraic equation.

Comparable data: Two or more data sets using the same standards and definitions for purposes of comparison.

Confidence: The risk of error that a decisionmaker is willing to accept.

Cooperation: Working together toward a common purpose.

Coordination: Combining parts to function harmoniously.

Data base: A repository for information.

Discrete variate: A variate that can only take on a discontinuous set of values.

Edit: To ensure conformance of data by comparing each item with a standard list of valid entries, codes, and so forth, or a valid range for that item.

Evaluation: A determination of the worth, quality, significance, amount, degree, or condition of something by careful appraisal and study.

Hierarchal classification: A classification whose successively lower (more specific) units fit within separate units described by the next higher (less specific) level in that system (Schwarz and others 1976).

Integrated inventory: An inventory or system of inventories designed to meet multifacility, multilevel, multiresource, or temporal needs.

Integrated monitoring: The systematic measurement of universal and specific resource data that can be used to test for attainment of specified standards or objectives or to evaluate the validity of key assumptions in a decision.

Inventory: The process of gathering and summarizing or an accounting of goods on hand. A survey or its immediate product that indicates the instantaneous state of a system.

Monitoring: The process for measuring and evaluating data on key variables to determine if objectives or standards are being met; the collection of serial data to evaluate trends as well as to understand how a system functions. For renewable resources, monitoring is the systematic measurement or analysis of change in ecosystem components or processes to determine the effects of actions on the environment and how actions and effects comply with laws, regulations, policies, and executive directives, as they are expressed in objectives and standards.

Multilevel integration: The creation of a common data set to provide information at two or more decision levels within an organization, such as forest-stand examinations, that are used for timber resale work as well as to verify input data for forest planning growth simulators.

Multilocation integration: The creation of two or more separate data sets for comparison or aggregation. Examples are a forestwide data set created by two or more districts or a common national data set created by two or more Federal agencies.

Multiresource integration: The creation of a common data set consisting of one or more variables (universal data) used for two or more different resource functions. It is an attempt to record part or all of the biological and physical conditions of a site regardless of the intended uses of the resource.

Multivariable (variate) inventory: An inventory consisting of two or more variables (variates).

Pixel: Contraction for picture element. The smallest, most elementary areal constituent considered by an investigator in an image (also called a resolution cell) and the value assigned to that resolution cell. Comparable to one of the many dots making up the picture on a television screen.

Plan: Any detailed scheme, program, or method prepared to accomplish an objective or goal.

Precision: An expression of the way in which repeated observations conform to themselves.

Production function: A mathematical relationship that shows how inputs of various physical factors are related to changes of outputs, for example, the effect of thinning on the rate of timber production or thermal cover for wildlife.

Reinventory: Remeasurement of an entire survey area to replace an inventory in its entirety, as distinct from *continuing inventory,* which is the systematic updating of selected variables within an existing inventory.

Remote sensing: The science and art of obtaining data and information about an object or representation of that object without coming into physical contact with the object.

Sample frame: The total population of possible sample units or plots within a survey area. A frame may be a listing of all pastures within a range allotment, all stands within a forest, all pixels within a Landsat scene, all possible 0.1-hectare plots within a big-game winter range, etc.

Sample plot: A sample unit of known area or shape.

Sample size: The number of sample units established in a given area.

Sample unit: One of the specified parts into which the population has been divided for sampling purposes. Each sample unit or plot is regarded as individual and indivisible when the selection is made (Kendall and Buckland 1972). A pasture, stand, pixel, and 0.1-hectare plot are each examples of sample units.

Sampling design: The method to determine which sample units will be measured or observed such as a systematic sample or stratified sample.

Sampling error: The standard error of the sample estimate expressed either absolutely or as a percentage of the estimate.

Sampling intensity: The number of samples taken per unit area.

Standardization: The act of bringing items into conformity with quantitative or qualitative criteria commonly used and accepted as authoritative.

Statistically valid design: A design in which sample units are chosen that are representative of the population, utilize objective observations, and permit the calculation of sampling error.

Stratified sample: A sample selected for a population that has been stratified, i.e., divided into parts. The process of stratification is usually undertaken by dividing the survey area into sub areas on a map or through interpretation and classification of points from remote sensing imagery.

Survey area: The entire land base for which information is sought, i.e., allotment, forests, Landsat scene, or winter range. The area for which information will be summarized and analyzed and upon which predictions and decisions will be made. It is the aggregate of land area from which sampling units are chosen (also called inventory or survey unit).

Systematic sample: A sample that is obtained by a systematic method as opposed to random choice, for example, making observations at equally spaced intervals on the ground.

Temporal integration: The creation of two or more data sets covering the same survey area established at two or more different times to estimate or measure changes (also called successive or time-series inventories).

Universal data: Data that are basic to many uses and from which many kinds of information can be derived.

Update: To address change within an inventory cycle. The procedure of modifying a portion of an existing data set of a survey area through mechanical or modeling procedures to the present. For example, as forested lands are cut over, the volume is subtracted from the data set; as the forest grows, the volumes are expanded through a growth processor or model.

An integrated system of inventories must be 1) adaptable to a wide range of ecological conditions; 2) usable at different levels of management (specific actions to broad regional efforts); 3) replicable and suitable for statistical analysis; 4) flexible enough to fulfill different information needs, i.e., emphasizes universal data; 5) adaptable to a monitoring program; and 6) suitable for use with automatic data processing (ADP) (Armantrout 1983). Development of such a system requires bringing together knowledge from all disciplines, maintaining lines of communication, and providing an efficient and coordinated system for collection, storage, and retrieval of data. An underlying assumption of integration is the ability to structure fragments of knowledge in a manner that permits many things to be related to each other meaningfully (Forrester 1980).

The principles for integrating inventories provide the framework for obtaining meaningful data in an efficient and timely manner.

We have developed four principles—cooperation and coordination, standardization, objectivity, and control and responsibility—for integrating resource inventories. Without a commitment to the first principle, the remaining three are useless.

Cooperation and Coordination

The most important elements for successful inventory integration are cooperation and coordination—cooperation between data collectors and ultimate information users so that inventories meet an organization's objectives and coordination among data collectors so that the required information is gathered most effectively.

Cooperation is needed to 1) establish minimum requirements for meeting information needs irrespective of agency or organization; 2) establish inventory standards providing uniformity between data collectors; 3) provide minimum quality requirements against which inventories can be evaluated; 4) eliminate unnecessary duplication of data collection; and 5) increase utility of resulting information.

Coordination improves cost effectiveness by eliminating redundant data collection and reporting and by incorporating alternative measuring and sampling techniques. Involving all interested parties, clearly identifying intended uses, defining areas of responsibilities (particularly when inventories may be conducted by two or more individuals or agencies) and designing inventories that are multipurpose all improve efficiency.

Standardization

Standardization adds to the value of information, for information then becomes useful to more people and data can be compared and combined. Definitions, classifications, and measurements require standardization, but to encourage innovativeness, flexibility in how those standards are met should be allowed.

Terminology—Standardization of attributes recorded in various inventories is the key to integration along with the map or geographic position of that set of attributes (Beltz 1984). There is no subsitute for a list of required data elements with standard definitions and allowable codes. Regardless of the type of inventories being developed, terms used to describe the data elements and resources must be agreed upon. It is futile to set standards if terms have different meanings to different people. For example, even though resource specialists agree that the variable aspect should be measured on all field plots, unless the term "aspect" is carefully defined, its utility may be limited. To a forester the term means the slope direction; to a range manager it may be the general vegetation type present. Therefore, some common agreement on terminology for inventory variables is essential.

Inventory variables include those that are assigned, observed, measured, and computed. Assigned variables are usually data identifiers such as State, county, ownership, watershed, administrative unit, and universal transverse mercator (UTM) coordinates. Tree species is an example of an observed variable; tree diameter, a measured variable; and tree volume, a computed variable.

It is particularly important to agree on those items that are observed and measured. Those that are computed can often be converted by use of computer software or hand calculators. If automatic data processing is to be used, it is desirable to have uniform coding and format for the assigned and observed variables.

Standardizing terminology begins with the identification and layout of output products sought (tables, maps, graphs). Next variables needed to produce the products are listed. Existing definitions and terms used to describe those variables are assembled. (Never make up a new definition or code if one is already in use (Johnston 1984).)

A cut-and-paste approach (or computer program) that puts the existing definitions for each term on a single page is the next step. A separate page is allowed for each definition. If a definition is unavailable or in conflict, that is noted on the appropriate page for later resolution. When the set of definitions is complete and the conflicts resolved, the list or data element dictionary will be ready for comparison with similar lists for other functions and disciplines or managers to use. Comparisons of such organized definitions help isolate areas of conflict and overlap identifying areas for negotiation and resolution (Goforth 1984).

Definitions should include the name, description, units of measure, precision level as appropriate code, format in relation to outputs and data dictionary, and a reference to the source of the agreed-to definition (Kosco and others 1984). Collins (1984) further recommends that the dictionary include information as to whether the variable is observed, measured, or calculated. If calculated, a reference to the program or system used to generate the information should be included. Once the dictionary has been built, a process for maintaining and updating definitions has to be established.

Classification Systems—A classification system identifies and groups like features having similar biotic and/or abiotic properties about which users make meaningful inferences.

A classification system provides 1) a basis for statistically valid collection procedures and refinement of data; 2) a framework for the organization, compilation, and presentation of statistics; 3) a set of building blocks suitable for rearrangement or expansion for special studies or special-house classification systems; 4) a means to characterize significant differences in relations to treatments; and 5) in some instances, a design for computer programs for processing, storage, retrieval, and manipulation of data (UNECE and FAO 1982). In some cases a uniform system also provides an initial basis for monitoring.

Classification should be 1) in accordance with inventory objectives; 2) defined with precision and without ambiguity; 3) adapted to the type of items surveyed; 4) matched as closely as possible to the needs of the most important users; 5) compatible with concepts and classifications already in use (and in use in the past for comparisons between assessments) at each or all decision levels; and 6) applied uniformly to obtain a consistent picture for the whole (FAO 1981).

It is important to note that many classification systems may be used within the same inventory. A technical classification is the hierarchical aggregation of information into more general categories for decisionmaking at high administrative levels. This aggregation is usually done without regard to geographic location or juxtaposition. The summation of data by county, State, region, or nation is an example of a technical classification.

Another type of classification is a natural or ecological system, in which ecosystems are grouped hierarchically into larger systems to show spatial relationships that are significant to natural functions and processes. These relationships determine how a system will respond to management. Table 1 presents an example of such a system. Plant associations, ecological type classifications, and mapped ecosystem framework are used to coordinate inventories to define land capability and evaluate the production potential of resources (Schlatterer 1984). For additional examples see Husch (1966), Wertz and Arnold (1972), and Driscoll and others (1984).

For resource management, lands need to be classified or stratified into units that are identifiable and mappable, respond similarly to management activities, and can be spatially grouped for analyses. A classification system is used in the inventory process for allocation of samples or for compilation of data. In either case the strata must be logically related to items of information sought, represent a grouping that has meaning to the manager or decisionmaker, generally exist in nature but may be artificially created, be mutually exclusive, represent a relatively homogeneous condition that can be defined in specific terms, and be developed as closely as possible to accepted definitions (Lund 1978c).

If used in preinventory stratification classification units must be recognizable or interpretable from remote sensing or existing maps. In postinventory stratification units must be extractable from the available inventory data.

For example, if crown cover is chosen as a criterion for classifying forest land, statistics relating to forest land are additive only if a uniform percentage of crown cover is available from the inventory. Therefore, variables that would be used to define new strata or classes must be anticipated and included in the inventory design.

Measurements and Observations—Measurements in an integrated system of inventories should use commonly accepted and agreed-upon standards. Differences in standards between organizations or uses should be resolved in favor of the higher degree of precision if practical. For example, it is difficult to combine data about trees when total height was measured in one inventory and merchantable height in another inventory.

In general, it is more difficult to integrate discrete data than continuous (nondiscrete) data, usually because of variability in definitions of the categories of nondiscrete data. It should be kept in mind, however, that it may be impractical to measure data, and one may have to resort to using discrete classes. This can introduce error and should be avoided when possible.

The quantitative values in an inventory should permit the computation of estimates for any purpose. The units chosen should be generally accepted by the appropriate professional disciplines. Specifications based on quantitative measurements can be standardized more easily than can qualitative characteristics.

In developing standards of measurement, potential changes in uses, technology, and salable products should be considered. In anticipation of changing utilization standards for timber products, for example, it may be desirable to measure all trees, rather than only trees of sawtimber size.

Procedures for making the measurements should be standardized to the extent that the techniques are compatible (Dixon 1982). Field units could be exempted from following standard practices with documented justification to the contrary. The documentation should include evidence that integration between decision level, agencies, or resources is not compromised by the nonstandard procedures (Gryczan 1984).

Table 1—*Hierarchical mapping classification incorporating the land systems inventory*[1]

Level	Basis	Further definition	Approximate area in square kilometers
Domain	Subcontinental areas of broad climatic similarity		2,500,000+
Division	Subdivision of a domain determined by isolating areas of differing vegetation and regional climates		250,000+
Province	Broad vegetation regions with the same type or types of zonal soils		25,000+
Section	Climatic climax vegetation at the level of Kuchler's (1964) potential natural vegetation types		2,500
District	Part of a section having uniform geomorphic features at the level of Hammond's (1964) land surface form regions		2.5 to 250
Landtype	Manifest elements, soils, landform vegetation (first order stratification)	Group of neighboring landtypes with recurring pattern of landforms, lithology, soils and vegetation associations (forest level planning)	2.5 to 250
Landtype	Manifest elements, soils, landform, vegetation (second order stratification)	Group of neighboring landtype phases with similar landforms, soil series, or families with similar plant communities at the association or habitat type level (broad level resource planning)	.25 to 2.5
Landtype	Manifest elements, soils, landform, vegetation (third order stratification)	Group of neighboring sites with similar landform features belonging to the same soil series and the same or closely associated vegetation types (detailed resource and project planning)	.025 to .25
Site	Represents integration of all environmental elements (units generally not mapped).	Character of microrelief, single soil type or phase, and a single vegetation type phase and/or union (point at which inventory data are taken)	.0025 to .025

[1] Adapted from Bailey, Robert G. Description of the ecoregions of the United States. Miscellaneous Publication 139; Washington, DC: U.S. Department of Agriculture; 1980. 79 p.

Objectivity

Objectivity in inventory designs is needed so that data from different sources can be compared and aggregated. Objectivity is maintained through the use of sound sampling strategies. The proper choice of sampling strategies involves the minimizing of bias, the constructing a sample frame, and the selecting of a sampling technique.

Bias—There are three recognized sources of bias: measurement, selection, and estimation.

Measurement bias—Two types of measurement bias are possible—personal and instrumental. Personal bias is due to error by the measurement taker; instrumental bias is due to error inherent in the measuring instrument. Measuring the diameter at breast height (d.b.h.) of a tree at 1.36 meters instead of at 1.37 meters could introduce personal bias as could using too large or small a plot. Estimating herbage biomass from 0.011-hectare plot instead of a 0.010-hectare plot could result in a positive personal measurement bias. Rounding to a favorite digit (5 and 0 tend to be favored) or consistently counting boundary samples as "in" or "out" are other examples of personal bias. This type of bias can generally only be detected by comprehensive quality control monitoring, i.e., remeasuring part of what a field inventory crew has done. Training crews thoroughly can minimize this problem.

Instrumental bias may include the overestimation of the diameter of trees that are elliptical in cross section, by using diameter tapes, or the use of improperly calibrated prisms to determine basal area. Most optical dendrometers incorporate some bias. No fully objective conclusions can be drawn from a sample if a considerable amount of measurement bias occurs.

Selection bias—Selection bias refers to the selection of sample units that are not representative of the population of interest. As stated by Yates (1953), "The principle objective of any sampling procedure is to secure a sample that, subject to sample size limitations, will reproduce the characteristics of the population of interest as closely as possible." This problem is minimized if the sample is obtained in a totally objective manner. Fully objective conclusions cannot be drawn if selection bias is suspected to exist. Yates distinguished the following types of selection bias:

- Deliberate selection of a "representative" sample.

- A selection procedure depending on some characteristics correlated with properties of the units of interest. An example of this situation would be percent of ground cover being used in the sample selection process in a range survey, where forage production is the real item of interest. Note that this procedure is acceptable if the differences in probabilities of selection for ground cover and forage production are known and are adjusted for in the subsequent estimation process.

- Conscious or subconscious bias in the selection of a "random" sample. An investigator may allow his or her wish to obtain a certain result influence sample selection.

- Substitution of samples. For example, an unprofessional field crew may take a sample at the edge of a swamp rather than in the swamp as required, particularly at the end of a hard day.

- Failure to measure all the chosen samples. For example, a field crew may not be able to locate a given pine beetle plot preselected for ground sampling.

Sampling units must be randomly selected and be mutually independent to assure that each individual of the population has an equal chance of being selected as the sampling unit. Systematic sampling, a system often used in resource inventories, approaches these requirements. The selection bias may be lessened somewhat in a systematic sample by choosing the first sample unit randomly.

To completely avoid selection bias, the sample should be drawn entirely at random or at random subject to restrictions that improve the precision but introduce no selection bias. Such restrictive sampling schemes, such as stratified, multiphase, and multistage sampling, are discussed at length in any survey sampling textbook, Cochran (1977), for example.

Estimation bias—If data are collected with no measurement or selection bias, they may still be combined to yield biased estimates due to incorrect statistical assumptions. If correlations can be established, ratio or regression estimators may be more reliable than simple random sampling estimators.

Sample Frame—Although it may not be necessary to use the same design for integrated surveys, it is often desirable to employ a common sampling frame. A common frame can establish a minimum level of sampling within a common survey area. It also identifies the base sample where sampling responsibilities are divided. In addition, a predetermined frame may allow some inventory work to progress ahead of other work.

The cost of constructing a frame is usually lower than the cost of measuring the sample units. In the case of multiresource (or multiorganization) inventories, the potential common frame may therefore be based upon the sample units for the resource use (or organization) requiring the most detailed information (i.e., all potential 0.1-hectare plots in lieu of all stands). Such a frame would ensure that all resource needs potentially could be met.

The minimum sampling intensity should be based upon the function requiring the least amount of information. For example, a timber survey may require only 2 percent of an area to be surveyed whereas wildlife may require 10 percent. To sample for both timber and wildlife on 10 percent of the area would impose a cost on timber that is not needed, whereas to sample at an intensity less than 2 percent would meet no one's needs. Thus 2 percent would be the minimum intensity required in this multiresource inventory. Sampling intensities and data collection for other attributes (wildlife in this case) can then be increased when and where needed (Lund 1978a).

Sampling—There are basically two sampling choices: statistical (probability) and nonstatistical (nonprobability) sampling.

Cunia (1982) lists four situations in which nonstatistical sampling may be justified: a) variations between elements of the population are large and sampling is expensive; b) the needs for information about some population of interest are immediate and a decision must be made by management before the results of a well-planned and well-executed statistical sample can be secured; c) funding is unavailable and the only alternative is to use existing information and extrapolate to the population of interest; and d) approximate knowledge about some population parameters is required to design a statistical sample. Small subjective samples may provide the required knowledge.

Because of its inherent inability to supply information about the reliability of the sample estimates, the nonprobability sample should be avoided whenever possible, particularly when the resulting data are to be interpreted by many users. Nonprobability sampling, however, can be devised quickly. Because less information is usually obtained, the method is usually less expensive, can be implemented faster, and in some very special sampling cases, may be more reliable than statistical sampling. Unfortunately, the latter conclusion is impossible to prove mathematically.

Sampling errors and estimates of precision can only be determined when statistically valid designs are used. Statistical sampling is generally required when inventories are to be compared or combined. Thus statistical sampling is essential for designing integrated inventories.

Control and Responsibility

Control—Control provides the mechanism for ensuring inventories are carried out according to specifications. Control includes choice of area bases, timeframes, and data collection, compilation, and summary processes. Control should be established in an inventory plan and begun before the first field plot is established.

Area control—Decisionmakers usually require area statistics as well as volume and production information. All those concerned with integrated inventories must utilize the same area control base from which to compute areas. Without an agreed upon base, there would be no means to determine if areas are omitted or duplicated. The sum of the mapped and/or survey areas must equal the total area of interest.

Timeframe—In addition to utilizing a standard land base, inventories should also be within compatible timeframes. If compatible timeframes cannot be used, it is often necessary to update or "grow" the inventory through simulation models to make the data compatible. The models used, as well as the coefficients, may also become a form of control.

Data collection, compilation, and summary—Measurements and observations should be made as objectively as possible. Detailed instructions should be provided for each step of the inventory from measurements to ensure uniformity. Checks should be made throughout the inventory to ensure procedures are being followed.

A central authority should be provided in case procedural questions arise.

Responsibility—Assignment of responsibility indicates who will do what, when, and how. Responsibility also includes assignment of authority to resolve any conflicts or questions that may arise in the course of the inventory. This authority could monitor the inventory work, make changes in inventory methodology, and ensure that users understand the processes and correctly apply the results (Masse and Greene 1983).

An inventory may be a product (an accounting of goods on hand) or a process (the procedure used to count the goods on hand). Integration can be obtained by working both with the products and the processes.

There are four types of inventory integration that we will consider in this report (fig. 1), including inventories that are used to:

1) Compare information with that from other locations (multilocation integration).

2) Meet additional information needs for a higher or lower decision level (multilevel integration).

3) Meet the information requirements of several functions at one location (multiresource integration).

4) Monitor change and predict trends (temporal integration).

A large organization, such as the U.S. Department of Agriculture Forest Service, may demand all four forms of integration. Therefore an integrated system of inventories rather than a single inventory may be needed to meet an agency's information requirements.

To design such a system, it is necessary to understand the requirements, problems, and options for each of the four forms of integration.

Multilocation Integration

Multilocation integration is used to compare the resources of may sites with the intent of implementing an action on at least one of them or to pool or aggregate resource data from all the sites for a common purpose or objective (fig. 2). Locations may be timber stands, households, manufacturing plants, areas administered by different agencies, owners, States, nations, and so forth. They are the basic survey units that will be compared or aggregated.

Needs and Requirements—Multilocation integration requires that:

- Locations be mutually exclusive (boundaries do not overlap) and data from all locations must be complete (all locations are accounted for).

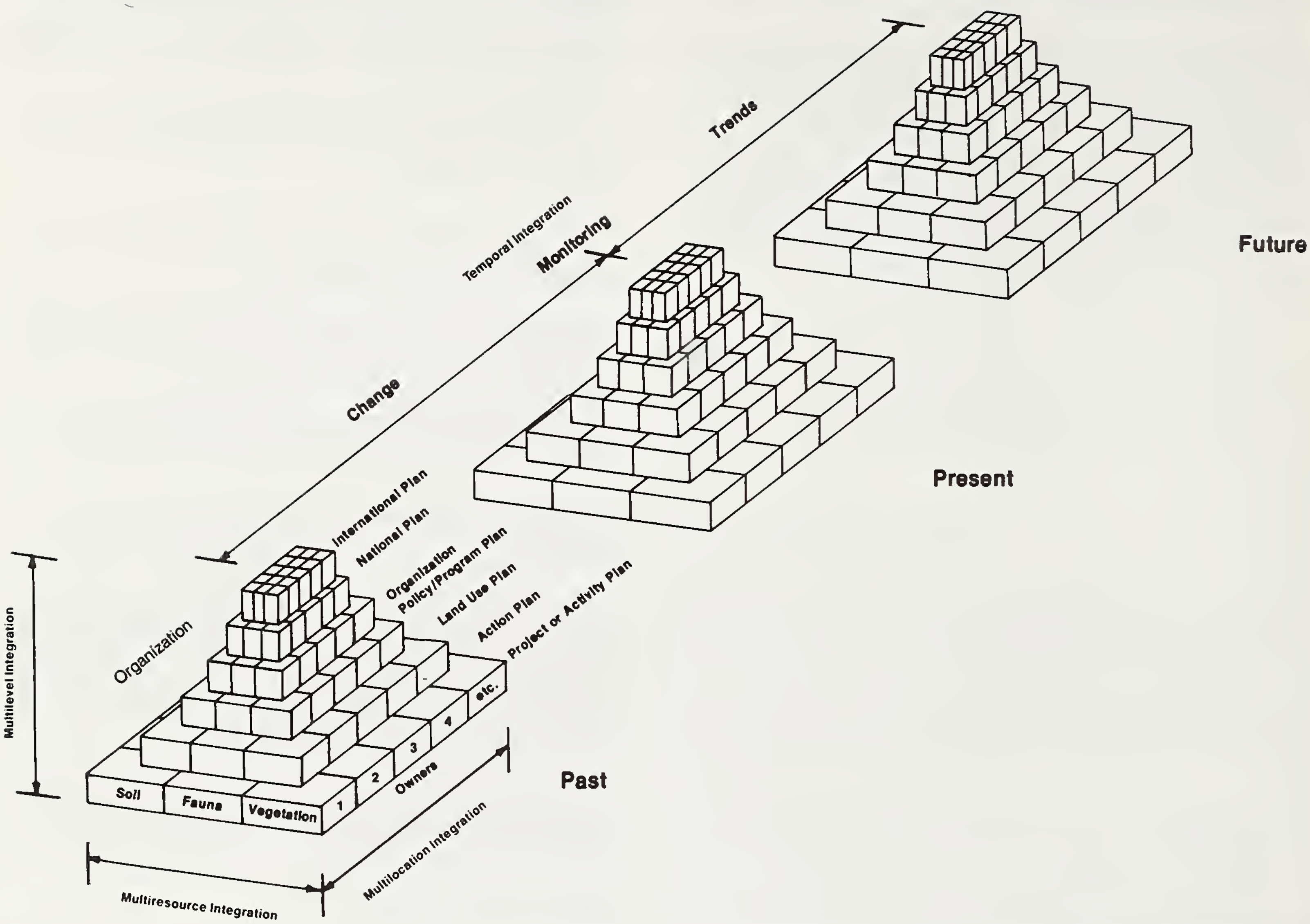

Figure 1—*Resource inventories involving multilocation, multilevel, multiresource, and temporal integration are building blocks for an organization's information needs. Cooperation, coordination, standardization, objectivity, and control are required to achieve integration.*

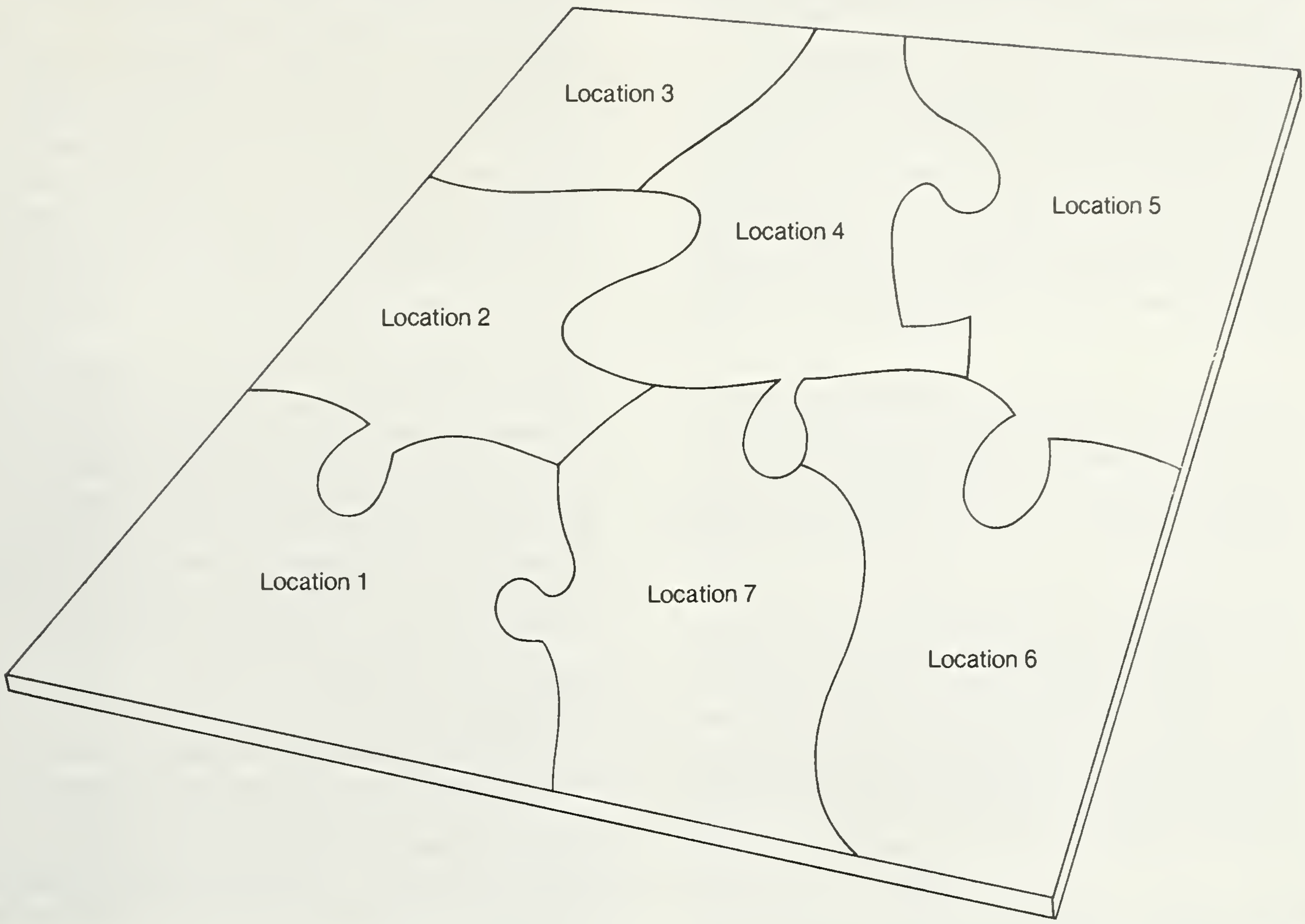

Figure 2—*Inventories must be coordinated and standardized to produce comparable and aggregable results in a multilocation integration.*

- The inventory of each location must be based on complete enumeration or on a statistically valid sample.

- Common definitions and standards must have been used or data collected in such a manner that they can be converted to common definitions and standards.

- The information produced from each inventory includes estimates of the mean (or total), the standard error of the mean (or total), and the probability level at which the standard error is calculated.

- An individual, group, or organization is designated a specified common repository.

- The repository is charged with the comparison and/or aggregation resultant data and given the authority to do so.

- An efficient feedback system is in operation for returning resultant outputs to users for modifying systems or implementing actions.

Special Problems and Considerations—Problems arise when any of the above requirements are not met and become increasingly difficult to resolve when the locations involve different agencies or organizations. Similar inventories conducted under different administrators often are heterogeneous, taken by data collectors with widely varying training, experience, and interests. The inventories may not be united by common goals, social commitment, views on the development of the resources, techniques, or standards. The more diverse the organizations that are collecting the data, the more difficult it is to compare or combine the data.

To ensure that inventories are compatible, it may also be necessary to designate a respository group that is responsible for leadership and quality control. The more authority that is provided to this central unit, the more compatible the inventories will become (Campbell 1974).

Recommendations—There are three basic options for ensuring multilocation integration: (1) each organization operates independently but uses common definitions and statistically sound inventory designs; (2) one organization provides direction and guidance for the inventories while the other organizations collect the data; and (3) one organization is soley responsible for the entire effort.

Option 1 leaves central responsibility for quality control, scheduling, etc., unaccounted for. The organization designated as the repository for the data may dominate the entire inventory process.

Option 2 avoids the problem of option 1 from the start. Responsibilities and leadership are assigned from the outset. The lead organization, however, is dependent upon the responsiveness of the other supporting organizations.

Option 3 puts sole responsibility for the inventory in the hands of one group or organization. It has the advantage that a significant cost savings (for example, from reduced overhead) may be realized by maintaining a well-trained and stable organization for basic, continuous resource inventory work. From the standpoint of efficiency option 3 is the most desirable; from a political standpoint it could be the least desirable, particularly if the cooperating organizations feel that they are the ones really benefiting from the inventory.

Any repository or lead organization should be established at the beginning of the planning process. Authority should be granted to the lead group in a formal agreement. At the least, the organization would provide guidance on collection, verification, storage and retrieval, and compilation of the data (Dangermond and Smith 1982). At most, the group would assume responsibility for the entire inventory process. The initial involvement of all cooperators is essential to a clear understanding of the purposes and methods of the inventory and the responsibilities of all involved, especially the lead organization and/or repository.

Staffing, funding, and procedural requirements for the lead organization need to be established, and an inventory plan should be developed jointly. The plan should set forth the inventory objectives, classification systems, data gathering responsibilities, timeframes, interpretation techniques, and reporting systems (Singh and Lanly 1981b). Standardized data sets and verification criteria should be established, and existing data evaluated against the criteria for usefulness.

Multilevel Integration

Land and resource management decisions are based upon resource inventories. Decisions may range from those needed to curb acid deposition on a global basis to those needed to set the selling price for timber on a 2-hectare tract of land. For effective data management and usage, inventories to support these decisions must be linked together.

A large Federal agency, such as the USDA Forest Service, may be involved in and require inventory data for as many as six decision levels including global and international, national, agency, administrative unit, activity, and project decisions. Each level of decision has its own information needs, uses, and requirements.

- **Global and International Decisions**

  Global or international decisions are needed to formulate appropriate policies to avoid depletion of the sustained supply of renewable resources and degradation of the earth's environment (FAO 1981). Global and multination inventories are used in developing 1) international assistance programs or action plans to reverse the depletion of resources and degradation of the environment; 2) foreign trade agreements to shift surplus to meet demands; and 3) cooperative agreements to control pests and diseases or to address other catastrophic occurrences. Global assessments and inventories are often conducted by international organizations such as the Food and Agricultural Organization (FAO) of the United Nations through the United Nations Environment Programme (UNEP). Information sought includes the present state of the resources and the rate and pattern of change. Such inventories may in turn influence an individual nation's policies for resource development and management.

- **National Decisions**

National decisions are needed for long-range planning within a given country. National assessments periodically provide basic and relevant data on renewable resources held by all types of owners within a nation, appraising changes in supplies of resources and demands for them, the outlooks for future, and possible alterations in these outlooks by changes in national programs and policies (Spada 1974). National assessments include descriptions of the present situation and estimated changes due to management, cultural influences, and natural or secondary factors (FAO 1980).

The data are usually assembled and compiled by a Federal agency or an association dealing with a specific resource product. The results are national reports that are used to develop Federal policies and programs for public and private land-administering organizations. The primary users of the information are the executive branch, Congress, and regulatory agencies, but private industries also use long-range estimates of production and trends to develop their own strategies.

- **Organization or Agency Decisions**

Decisions on policy and program development are needed to develop long-range plans for resource management at the highest level within a specific organization or agency (such as USDA Forest Service). The information required usually reflects current values and rates of change. Inventories conducted at this level may be considered as a prelude to the development of the resource. Inventories focus on the resource stock and the land's capability to produce on a sustained yield basis. The inventory units used in planning are usually based upon political or administrative boundaries (Lund 1982).

The information is used to develop an overall strategy for the management of resources within the organization's jurisdiction. It is used to define an organization's policy, to express that policy as a set of regulations, and to carry out and execute organization programs (Cunia 1978). Broad management goals and objectives and financial plans for the organization are the eventual products.

- **Administrative Unit Decisions**

Land use (preinvestment) decisions are needed to develop long-term direction for each management or administrative unit. (such as a national forest) within an organization. The resources and their condition and potential are described only in sufficient detail to direct the manager's attention to specific portions of the management unit for more intensive planning (Stage and Alley 1972). Area, volume, and production estimates are usually tied to capability or analysis areas within each management unit. Information sought for the capability units includes areas by land class, soil vegetation types, estimates of growing stock within the classes, and accessibility.

The resulting information is used to establish a unit plan or model for future management.

Inventories and analysis may also identify and rank opportunities for investment and allow managers to monitor the effectiveness of their actions. As such, the data base must be flexible to accommodate or support frequent revisions of the plan or to show changes wrought by variations in policies and management activities. The boundaries of the inventory unit for land use planning are usually based upon geographic, economic, or administrative areas such as States, watersheds, or national forests.

- **Activity Decisions**

Activity decisions, such as for timber management, are needed to determine what and where treatments are to take place. Inventories to assist the decisionmaker often include maps of vegetation conditions by treatment units; description of the vegetation and terrain within the units; and accessibility and relevant classification of the units with respect to the alternatives selected under the land use planning process (FAO 1980).

Land treatment units are usually delineated by vegetation type, size, density, or condition, or by productivity of the site or soil or both. The greater the diversity in the units, the greater the need to recognize additional units. Data observed include vegetation factors, potential productivity, accessibility, and economic factors in order to determine specific management actions to take place within the treatment unit.

The inventories are usually conducted by the field office within the management unit having the administrative responsibility. The output is a functional plan showing the treatment areas and indicating what is to be done when and where. The plan is used for the day-to-day operations of the lowest level field office.

- **Project Decisions**

  At the lowest level in an organization decisionmakers require estimates of the current resource situation for treatment units or groups of treatment units, such as timber stands, pastures, or range allotments, immediately before an action is begun. A timber sale is an example of this type of activity. The purpose of the inventory is to establish a value of the resource immediately before its sale or use.

Needs and Requirements—The information required at a given decision level is usually more general and broadly based than the information required at lower levels. Users of the information also differ. Users of national level information are usually more numerous and diverse than users of project level information. At the same time, information needs change as an organization matures. When first created, an agency may have need for (and access to) only broad descriptive information about its resources. As management intensifies, more detailed information is needed and more information becomes available as the lands are developed. Typical inventory characteristics for various decision levels are given in table 2.

Table 2—*Typical inventory characteristics for various levels of land and resource decisions*[1]

Decision level	Inventory unit(s)	Percent allowable sampling error		Data longevity (years)	Relative cost (dollars/ha)[2]
		Area	Product		
Global or International	Nations	+ 10/billion units	± 5/billion units	20–50	0.06
National (United States)	All States, organizations (or agencies)	± 10/billion units	± 5/billion units	10	.12
Organizational (USDA Forest Service)	Management units (MU)	± 10/area in each MU	± 15/total units in each MU	10	.25
Administration Unit (National forest)	Capability or analysis areas (AA)	± 10/area in each AA	± 5/total units in each unit AA	10	.62
Activity (Timber management)	Treatment units (TU)	Assumed correct in each TU	± 20–30/total units	5–10	17.30
Project (Timber sale)	Treatment or project unit (PU)	Assumed correct	+ 2.5–5/total units in each PU	0–5	61.75

[1] Expanded from Ashley (1978). All values expressed at one standard deviation.
[2] Based on 1974 U.S. dollars.

Integration between decision levels or multilevel integration is usually required to provide a continuous flow of information and management direction between the highest levels in the organization and the lowest levels. This ensures that the lowest units are carrying out the policies of the agency and that policies are made based upon the most recent data available.

Multilevel integration ensures that inventory processes and programs are structured, implemented, and coordinated in a manner that will meet legislative and policy requirements and provide decisionmakers with the information necessary to make sound decisions on land use (Lea 1981). Multilevel integration of data bases requires linking management direction from higher to lower decision levels and accounting for, aggregating, and using information supplied from below.

Special Problems and Considerations—Problems with creating integrated data bases to serve many decisions levels include how to identify and rank an organization's needs and how to decide on how many inventories to conduct.

An inventory system designed to support national assessments and appraisals cannot provide all the detailed information required to meet all project level needs. Similarly, the detail of information required at the activity or action decision level of an organization may not be needed at the policy formulation level. The costs of conducting an inventory that would meet all needs would be prohibitive and the quantity of data overwhelming (Joyce and Hoekstra 1984).

Recommendations—The option and recommendations for solving the above problems center around defining information needs and inventory design.

Identifying Information Needs and Setting Priorities—There are two approaches generally used to determine information needs. A top-down approach (fig. 3) starts with information needs being defined at the highest echelons, and at each subsequent decision level more information is added to meet more local issues. A problem with this approach is that the people collecting the data at the project level may feel burdened collecting information for which they cannot see a use. Consequently they prefer a bottom-up approach (fig. 4).

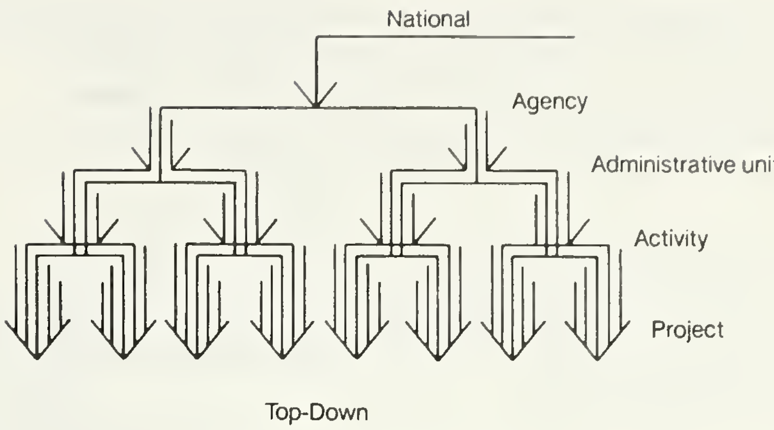

Figure 3—*Top-down approach to defining information needs. Information requirements are defined at the highest levels first, with each successive level adding to the requirements.*

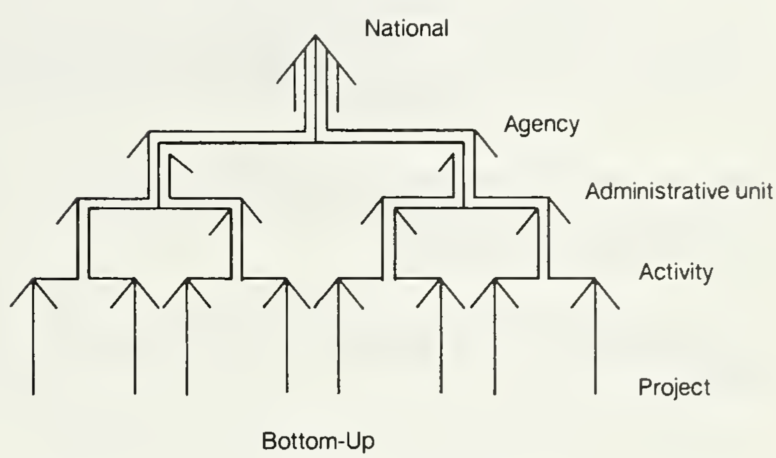

Figure 4—*Bottom-up approach defining information needs. Information requirements are identified at the lowest echelons and aggregated upward.*

In the bottom-up approach, the information requirements are defined at the local level and accumulated upwards. The disadvantage is that the information identified may not include the information required at the top level of the organization.

It is assumed that information needed at the top decision levels in an organization is needed at subsequently lower levels. Thus a top-down, rather than a bottom-up, approach is preferred when developing multilevel information needs.

To develop an integrated information flow, information needs and reporting formats must be identified at each planning level, starting at the highest or broadest level and working downward. This procedure establishes a minimum core of information required at all decision levels and ensures that the policies, regulations, and information needs of the organization are followed and fulfilled (fig. 5). The inventory data must be provided from the field or other appropriate lower level in the organization. The commitment to provide information from the lower levels will only be as strong as the need for the information as perceived by the field. Consequently, field units will be more cooperative in supplying information when they clearly understand why the information is needed and how it will be used to serve their needs.

Hoekstra (1982) recommends the following interactive steps to ensure that the information needs of an organization are being met.

1. Determine kind and quality of information required.

- Obtain or develop a current functional organization structure.

- Obtain a statement of information needs and sources from representatives at each functional level.

- Ask the representatives to review the compiled statement of information needs.

- Develop an information needs document containing the objective, procedure, contributors, and a listing of information items.

- Reorganize the material in the document into a data element list or dictionary to remove redundancy and to standardize definitions.

- Achieve a consensus from the representatives at each function level within an organization on the elements and the definitions.

- Publish the data element dictionary and standards for use within the organization.

2. Determine the cost efficiency of information.

- Using the data element dictionary, ask representatives to provide a statement of the cost associated with each data element produced by their organizational unit. A statement of real or relative values associated with different quality levels for each data element is also needed.

- Calculate an aggregate value for each quality level of data element used by all units within the organization.

- Ask data management specialists to provide the cost of maintaining the information base in a form that allows timely and accurate retrieval.

3. If reorganization is a possibility, determine the potential impact of organizational change on information needs and flows.

4. Specify the use, evaluation, and analysis processing of the information associated with the three previous requirements.

Inventory designs—Successful multilevel inventories are designed so that the data collection system can be used for more than one planning level and for successive collection efforts (Williams 1984). To ensure the integrity of information, data collection and location of observations of the resource must be consistent through all relevant decision levels (Hagen and Dyke 1980).

In addition, the land base to which the decisions will apply must also be defined. The area at the broadest level must usually encompass the area at the next lower level and such succeeding level (fig. 6). The larger areas are often political or administrative, whereas those at the activity and action levels are often based on

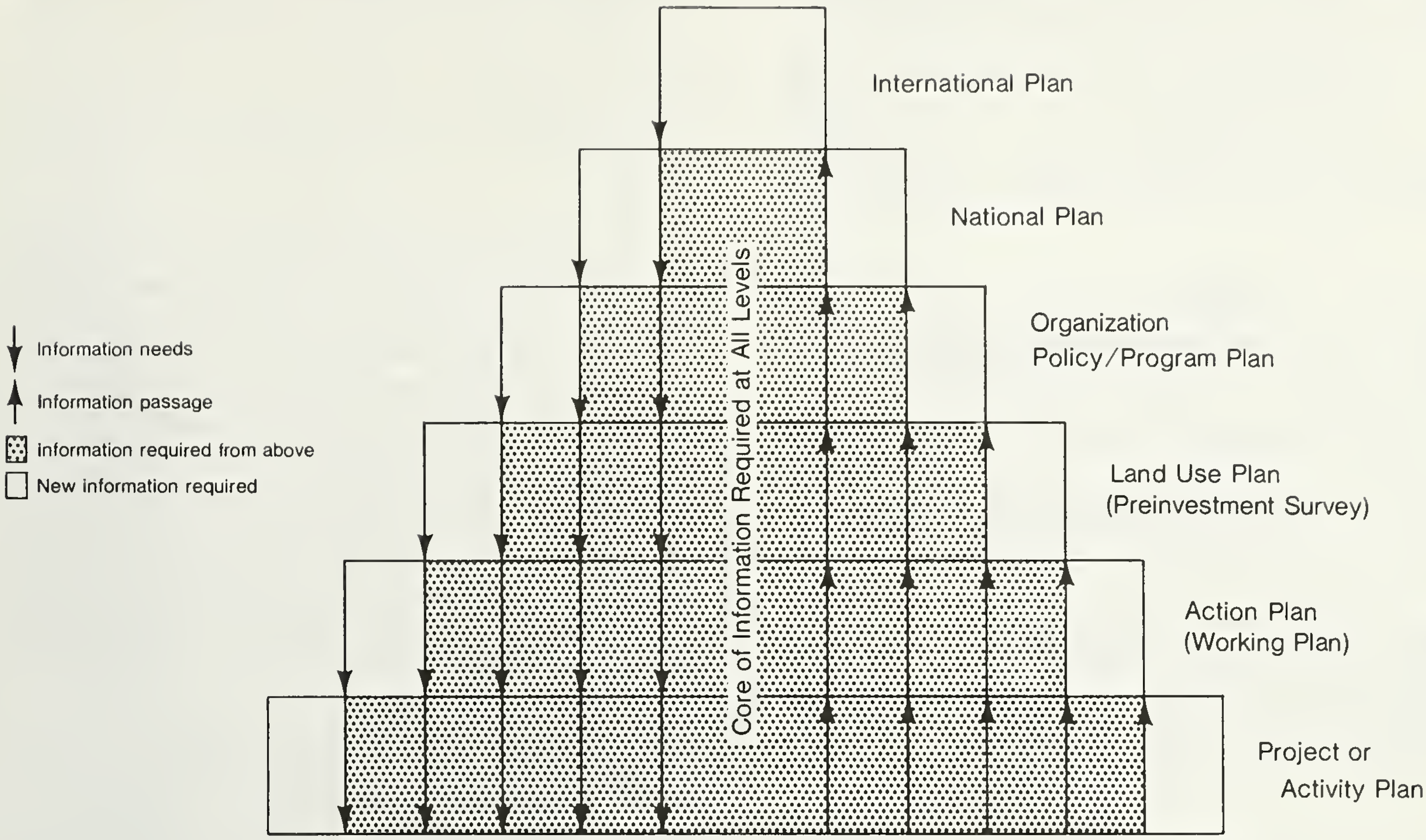

Figure 5—*Multilevel integration—a function of defining common information needs and sequential planning. Data needs from the broader, more far-reaching decisions dictate the minimum information requirements of successive lower levels.*

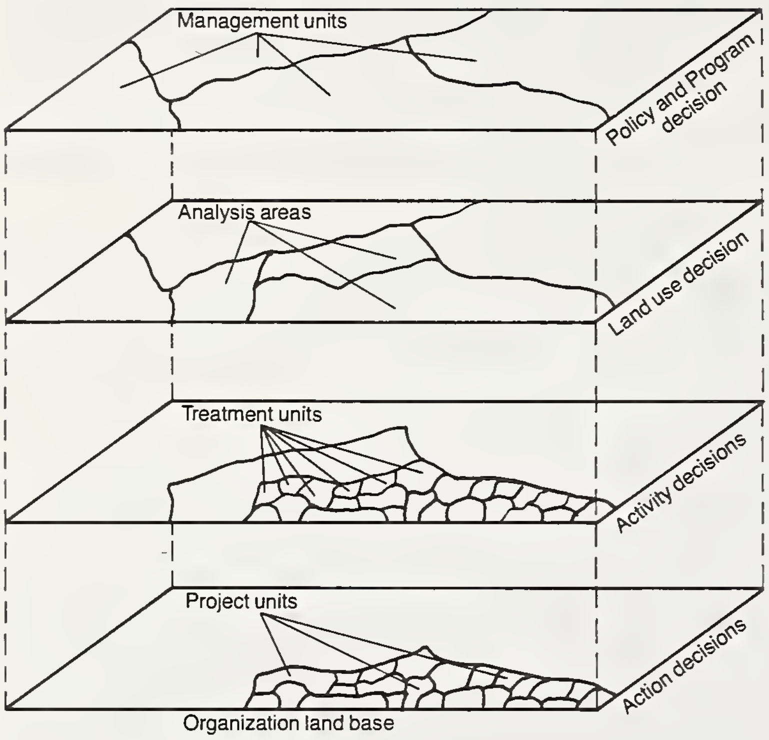

Figure 6—*Relation between the various inventory units and decision levels in multilevel integrated and coordination planning system. More intense data collection at the lower level is confined within the boundaries of the next broader decision level.*

ecological criteria. These areas may be used to define the maximum size of mapping units.

There are two design options for meeting multilevel information needs. The first option is to design a system in which the mapping and sampling is intense enough to meet the most demanding needs (that is, at the activity and action decision levels). The second option is to conduct two or more inventories on the same piece of terrain but at times corresponding to different stages of development.

The first option has the advantage that one inventory would provide compatible information for all decision levels. However, because all lands may not be managed at the same intensity, this option can be costly if the production potential and management intensity of the lands are low.

Under the second option, a broader decision level is chosen as a base. Again, it is assumed that this level of information would be required across all lands under the organization's administration. As with the first option, these inventories would be aggregated to provide more generalized information to the upper stages in the hierarchy. Unlike the first option, though, additional inventories for the more detailed planning levels would have to be conducted only when and where they are necessary, resulting in overall cost savings. Information from the broader inventory is used to enhance, expand, and supplement the more intensive surveys (Newton 1978).

In some instances, a combination of both options can be used. Detailed mapping may be carried out at the activity level to provide area estimates, while sampling for product estimates is conducted at the analysis area or management unit level. Smith (1982), for example, found that stand-by-stand inventories on forest industry lands tend to be piecemeal and insufficient in generalized planning activities. Broad-based inventories lacked the intensity and mapping detail required for intensive forest management. A design consisting of a collection of individual stands stratified within various levels of geographically ordered management units was adopted as a solution to the problem. In this design, each stand is recognized as a unique sampling unit from which basic data are derived, updated, and monitored over time. Lund (1978a, 1978c, and 1979b) provides detailed instructions for such a combined system. Extensive data together with the mapped information increases the applicability of the sample-based information for operational decisions.

Multiresource Integration

The term "multiresource inventory" can be interpreted so broadly that nearly any inventory qualifies or it can be considered in a very restricted and limited sense. If one equates the term multiresource with multivariant inventories, than nearly all inventories are multiresource. In a timber cruise for example, at least two variables are measured or observed; species and size or basal area. Thus, a timber cruise could be considered a multiresource inventory.

Similarly, although some inventories are designed and conducted for a single purpose, the resulting data could be reinterpreted for a variety of other uses. Using the timber cruise as an example, a wildlife biologist may reinterpret the species and basal area data to derive some wildlife habitat values (Nelson and Salwasser 1982). In the broadest sense the timber cruise could also be a multiresource inventory.

This primer considers multiresource integration as those inventories that are designed in advance to meet at least part of the information requirements for two or more resource functions for example, timber and wildlife management (fig. 7).

Needs and Requirements—In the United States, multiresource inventories generally have high priority on Federal lands, where pressure on the resources for nonpriced and nonconsumptive uses has increased. Multiresource inventories are needed to help land managers, policymakers, and the public to evaluate the condition, production tradeoffs, and alternative uses of the land and resources. Inventory emphasis should be focused on defining those things needed to evaluate contrasting choices (Kennedy 1984). The variables that are collected must be compatible with analytical models used (Buckman and Fight 1974). Potential information needs can include the entire spectrum of the biological, physical, and socioeconomic data and information. Information needed must be determined by the benefiting functions before an inventory and will vary according to the purpose and intent of the inventory.

Generally, a multiresource inventory uses common sampling units on which measurements are taken, provides estimates of resource parameters with emphasis on interactions, and provides opportunity for remeasurement of the sampling units at future occasions (Frayer 1978).

Ideally, information variables of interest should be collected at the same location and within the same time frame, thus eliminating duplicated data collection and linking various data elements together for evaluating use interactions, thereby providing the integration needed (McClure 1980).

Multiresource inventories should make maximum use of conventional inventory methods, be applicable year-round, cause no disturbance of vegetation on permanent plots, and be applicable by individuals with limited training or skills (Cost 1984).

Special Problems and Considerations—The primary problems of achieving multiresource integration are identifying the information that is needed and deciding how the data will be collected. Additional problems include the transfer of that knowledge to the data collectors and the development and testing of effective inventory designs (Bonnor 1982).

The identification of information needs is no small task. Each resource field has its own sphere of information that it requires (fig. 8). Areas of overlap are opportunities for integration and standardization. The USDI Bureau of Land Management (BLM) spent well over 40 person-years identifying all information that managers need for land and resource management planning. Over 2,300 data items were identified (Pulford 1981). To design a single inventory to provide all the information required would be an impossible task.

Design is also a problem. One of the greatest fallacies in many multiresource inventory attempts is the belief that the requirements for management information of all resources are equal in priority, detail, complexity, and coverage (Wakeley 1983). Items of interest may not exist at the same time nor may their sphere of influence be limited to the same area. For example, snow depth and production of annual vegetation cannot be measured at the same time. Hence, two inventories of the same area at different times would be justified. Migratory patterns of waterfowl and big game usually extend over a much broader area than a single vegetation type. Consequently, sample resource data collected within only one vegetation type may be inadequate. Two or more separate inventories may be required.

If multiple resource data are collected during the course of an inventory, plot configuration becomes a problem because different items of interest usually have different frequency of occurrence.

Another problem is finding qualified people to collect multiresource data. Many resource specialists do not want to collect data outside their own field or do not have the technical skills to do so (Hendzel 1984).

Some resource specialists do not trust each other's work. Similarly, many specialists do not want to relinquish their data collection authority. Knowledge is power, and those who control the data control power. To give up power is to give up the ability to influence decisionmakers (Sheehy, 1984).

Recommendations—As with other forms of integration, the special problems of multiresource integration are resolved through information needs assessment, design, plot configuration, and obtaining functional support.

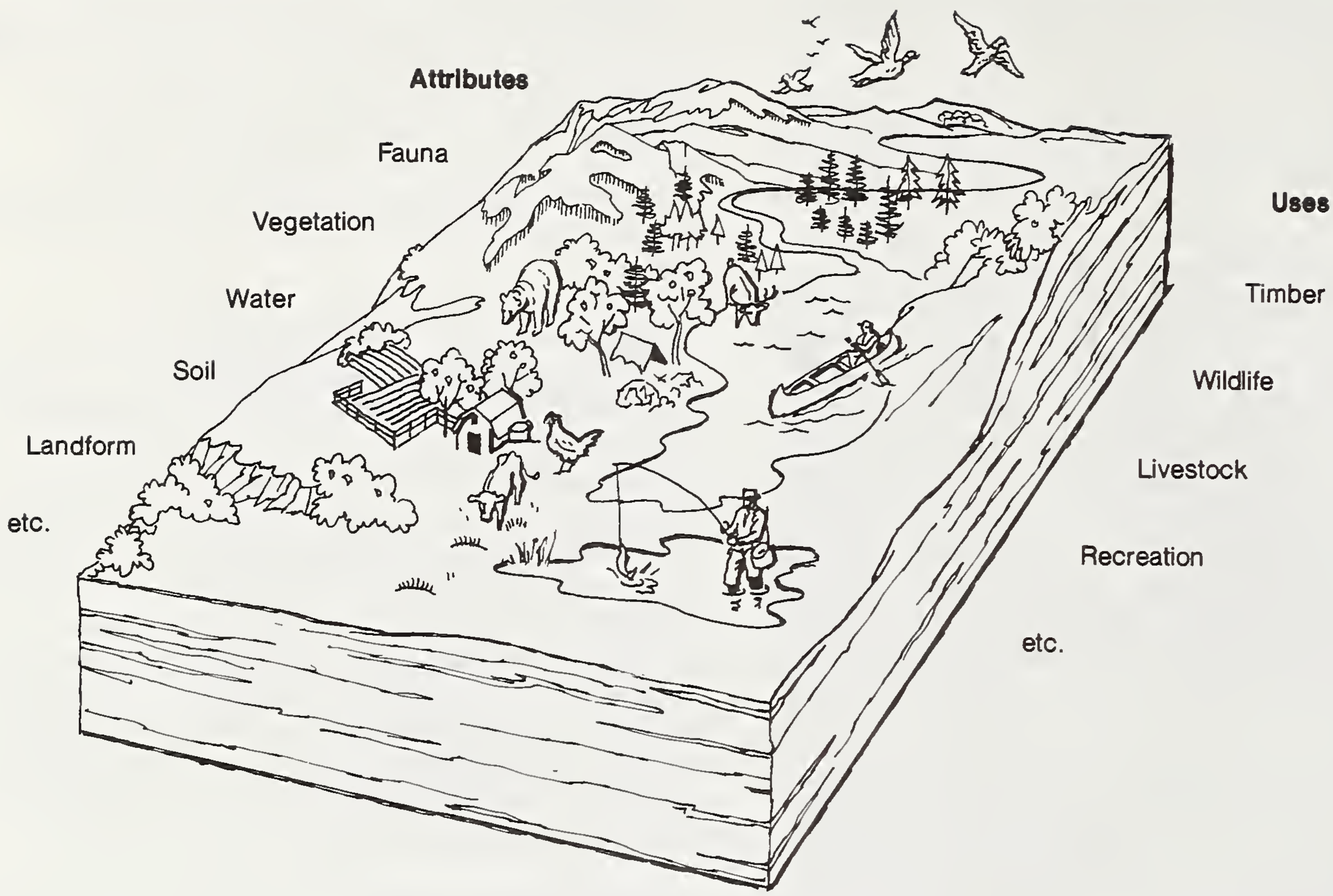

Figure 7—*Multiresource integration describes the biotic and abiotic attributes so as to permit interpretation for a variety of uses.*

Information needs—In multiresource integration, information needs are often inversely related to the size of resource programs (Kennedy 1984). In the USDA Forest Service programs with limited funding, such as wildlife management, tend to have very limited information whereas timber programs may have an abundance of data. The timber data is often easier and cheaper to obtain than wildlife data. Thus, there is often an imbalance of information between competitive uses. If an attempt is made to increase the data collection effort to improve the wildlife estimates, the cost of the inventory and the workload on wildlife specialists will increase (Teply 1984). Thus multiresource inventories could increase rather than decrease costs.

Rose and others (1981) advise avoiding collecting easily obtained data if the data have little impact on the inventory objective or if little is known about other variables that have a greater impact. They further advise not to collect detailed data on alternatives that for

Figure 8—*Each resource has a sphere of information needs. Overlapping areas represent opportunities for integration. The inner circle represents basic information common to all disciplines; the outer circle represents total information needs. Multiple resource inventories can be designed for basic, overlapping, or total needs.*

one reason or another will be eliminated at an early stage in the analysis process. For example, do not collect detailed timber data in areas where timber management is not feasible because of political constraints.

The primary information sought for most forest and rangeland decisions usually includes area data, green and woody biomass, vegetative production, and treatment opportunities (Dillard and others, 1984). Winward (1984) and Rudis and others (1984) developed the following as the recommended basic or core data needed by the United States Department of Agriculture Forest Service to produce this information.

1) Identifiers:

- State, county, forest, district, etc.

- Survey unit, management area, or other designated identifier.

• Sample unit location, UTM or state plane coordinates.

2) Vegetation: condition data, composition, dominance, frequency of species within association, productivity (see table 3).

3) Physiographic data: aspect, slope, elevation, gradient, position, slope length, landform, geography.

4) Soils: collect enough information to access the United States Department of Agriculture Soil Conservation Service Soils-5 data base. This contains the basic chemical and physical properties as well as interpretive information for every major kind of soil in the United States (Nordstrom 1984).

Data to be collected may include:

• Soil profile description: Horizon thickness, color, texture, and structure.

• Parent material (geology).

• Surface condition (for example, litter or humus duff layer).

• Soil sample for late determining chemistry (base saturation, pH, etc) and moisture and temperature characterizations.

5) Site potential: species occurrence; measure of species dominance (plurality of stocking); and plant association, if previously defined.

Table 3—*Vegetation characteristics needed for resource plunning (adopted from Rudis and others (1984))*

Vegetation characteristics	Functional life form										Units of measure	Measured or calculated
									Dead and down vegetation			
	Trees	Shrubs	Forbs	Gramoides	Mosses	Lichens	Aquatics	Vines	Litter	Other		
Species	X	X[2]	X[2]	X[2]			X	X[2]			Species level	Measured
Crown length width	X	X									Feet	Measured
Percent canopy cover	X	X	X	X	X	X		X			% of area	Measured
Height	X	X	X	X							Feet	Measured
Age/year of origin	X	X									Years	Measured
Density	X	X	X	X	X	X					#/area	Measured
Biomass, total and net	X	X	X	X	X	X	X	X	X	X	Wt./area or	Calculated
Production/period											volume/area	Measured
Percent dead	X	X									% total volume	Measured
Basal area	X										Sq. m./ha or Sq. ft./acre	Calculated
Size Diameter	X	X								X	Volume	Measured
Length	X	X								X		
Depth					X	X			X		Thickness	Measured
Decay stage	X									X	—	Measured
Damage	X										—	Measured
Condition of use[1]	X	X	X	X	X	X	X	X		X	—	Measured

[1] Includes presence of cavities, grazing activity, etc.
[2] Dominant species only.

6) Other: plot expansion factor or map unit area and date of survey.

Conant and others (1983), Avery (1975), Myers and Shelton (1980), and LaBau (1984) provide excellent reviews of techniques currently in use to collect these data items. Information requirements and techniques for measuring nonconsumptive uses will become clearer as research and experience intensifies.

Design — For multiresource inventories, Wikstrom and Hoekstra (1981) recommend that

• Data should be collected under an ecological classification system.

• Data should have the capability of being aggregated to different levels of resolution for analysis.

• Data should be collected from the same sample locations (but not necessarily at the same time) for interaction analysis.

• Sample locations should be distributed across the ecosystem(s).

• The inventory should provide measurements of change and relationship in the ecosystem.

McClure and others (1979) list four possible methods for obtaining multiresource information: 1) taking additional measurements and observations at existing sampling units within existing sample frames; 2) adding additional information through maps, overlays, and more sample data locations; 3) developing new sampling frames and designs; and 4) using information from other resources in its present form.

Clearly a mixture of these methods is a possibility too. Any of these options will work if a common survey or analysis area has been established and the estimates are confined to that area.

Method 1 is being used in a joint USDA Forest Service and Soil Conservation Service inventory of the forest lands of Maine (Ferwerda 1982). The two agencies are utilizing a sampling frame of point locations established for timber inventory to collect both timber and soils information. Other examples are presented by Lund (1978b), McClure and others (1979), and Lund and Kniesel (1975). Existing frames, however, may not extend across all the populations and may not be detailed enough to provide usable information for all the populations of interest.

Method 2 is one of the most common techniques used. The BLM, in its extensive forest inventory, added soils information to its timber data base by utilizing existing soil surveys overlaid on timber sample plots (Lund 1974b). This technique works well if the two surveys have the same resolution (definition of minimum size of sample units) or if broad-based integrated analysis is to take place. If a plot by plot analysis were made, correlation between the sample data and the overlay information would be weak. This does not mean that one survey is necessarily better than another, but that, because of resolution differences, comparisons should be made on a broader base.

Method 3 at the outset may seem to be the optimum procedure to use. A basic problem with this problem is establishing a common frame.

Multiresource integration requires the ability to collect, store, and retrieve information by a mutually agreed upon locatable land unit (Collins 1984). The locatable land unit or site serves several purposes including inventory, organization of information, communication, and information planning.

Some resource specialists are accustomed to using mapped sample units (an area sampling frame), while others prefer points. Johnston (1984) recommends that mapped units be used. These would be the smallest unit of land (10–15 acres or 4–6 ha) for which any resource will need information and have a uniform prescription; it is discrete, homogeneous to the extent possible, and representative of the most dominant resource. Such sites are further defined by ecological, soil, or vegetation characteristics (Mehl and others, 1984).

Mapped sample units are preferable for land management and activity planning. The use of mapped sample units makes it easy for the manager to find special conditions on the ground after the inventory, assuming the mapping portrays the information in question. It enhances spatial analysis. At some time, the resources will have to be mapped.

Lund (1978a, 1978c, 1979b) described a stratified sampling using mapped areas or polygons as a sample frame. A modification of this map sampling procedure is used by the BLM in its soil vegetation inventory method (Baker 1982). In this instance, it is essential that map unit boundaries coincide for all involved resources. Valentine (1981) suggests that this is only possible if a team of the necessary specialists goes to the field together at all times and considers all relevant criteria at the same time rather than sequentially.

Map legends are limited in what can be displayed; thus the location of and additional information on the mapped unit must be stored in some type of data base to provide inventory totals and summaries of selected conditions.

For making estimates of large areas, mapping all treatment units may be less efficient than using a grid of systematically located sample points. The use of a grid makes it possible to obtain the areas of different classes without bias or with less bias when determination of transition zones is difficult (Lanly 1976).

Systematic sampling is appealing because it distributes point samples uniformly throughout the area, regardless of the resources present (Dixon 1982). The USDA Forest Service Intermountain Forest Inventory and Analysis (FIA) unit is developing a new sample frame that covers all potential multiple resource populations by such a systematic grid system (Van Hooser and Green 1981). The Alaska FIA unit is also developing a common sample frame created through multilevel sampling of inventory timber, wildlife habitat, and soils.

Regardless of whether point or mapped sample units are used, the primary drawback to method 3 is the cost and time involved in creating a totally new sampling frame that meets each resource need. This is generally only feasible in areas where few previous inventories have been taken, such as Alaska.

Method 4 is the most common method used to integrate multiresource information. Information from a variety of sources is simply combined. This technique perhaps is the easiest, but may also be the least desirable, for the following reasons (Dixon 1982):

- Converting data to a common basis may cause bias if data are collected on sample units of different sizes.

- Without an assessment of general information needs, there is no assurance that available data are appropriate.

- Total cost of inventory may be higher than necessary because not all information collected is used and because some data may be collected more than once.

- Assessment of interactions among resource systems is difficult because variables are usually measured at different times and places.

If multiple map overlays are used, it is difficult to make interpretations. In addition, the final product may be unworkable for on-the-ground planning. If different mapping standards were used, it is unwise to transfer reinterpreted data from where they were collected. Empirical tests by Gersmehl, Napton, and Luther (1982) have demonstrated that differences can be large enough to render resulting maps virtually useless for planning purposes.

In general, if different standards, definitions, and techniques were used in conducting individual inventories, the reliability of using combined data should be questioned for any integrated analysis or comparisons that are made.

In summary, any of these four methods will work for integrating inventories if a common survey area is agreed upon. Method 3 is the most desirable when a totally new inventory can be implemented. Method 1 is the most desirable when continuity in inventories is important, if the frame can be extended to include all the populations of interest and if the sampling intensity is sufficient to meet the needs of the least demanding resource.

Plot configuration—Size and shape of vegetation sample plots deserve special mention in developing multiple resource inventories. As the number of variables in an inventory increases, the problems of plot size and shape, number of plots, plot distribution, and value of the information obtained become more critical because of the costs involved. Optimizing plot size (Wiant and Yandle 1980, Zeide 1980) and shape can reduce inventory costs, and at the same time provide more precise estimates of resource variables. Unfortunately, each resource has its own optimum unit; anything more would increase the cost and anything less would decrease the precision and accuracy of the estimate.

A plot is usually defined as a relatively small, fixed-area sampling unit of various shapes (circular, square, or rectangular). A special case of the rectangular plot is the belt or strip whose length is many times its width. The plots may also be variable-radius plots and variable-width belts or strips. The plot size is fixed for a given tree size, for example, but different for different tree sizes.

(1) Plot size

In general, plot size depends on the diversity of the variable of interest in the population. If the vegetation is very dense, as in timber regeneration or forage species populations, small square, rectangular, or circular plots used (0.1 to 2.0 meters in size) are used. The size of these plots often is determined by the size of a rigid vegetation sampling frame that can be carried conveniently into the field. Large plots would be nearly unmanageable in such situations.

If variables are to be measured by relatively inaccurate means such as an occular observation of canopy coverage, it is useful if the plot can be observed in one glance. Normally this limits circular, rectangular, or linear plots to about 2 meters across.

Relatively large plots tend to be used in large-scale inventories for less frequently occurring variables such as mature timber and are likely to be required in multiresource inventories. These plots range in size from 0.1 to 10 hectares. These large plots would likely be subsampled by various sizes and shapes of miniplots.

In general, large plots have the advantage of decreasing overall travel time in sampling, and potential border bias is less likely to influence results seriously. Small plots have the advantage of being sampled easily and are more efficient because their within-plot variability is small.

(2) Shape

The variable radius method of sampling (Beers and Miller 1964) is frequently used to sample trees. This is particularly true of one-time inventories made for timber sales, postlogging checks, or quick estimates for private landowners. Trees are selected proportional to basal area (in horizontal angle sampling) so that large trees have a higher probability of selection than small ones.

The size of the angle or basal area factor (BAF) to be used depends on management uses and stand conditions. Small basal area factors can be efficient for young stands, larger ones for old growth. A skilled field person is needed for this technique because serious bias can enter into the estimation process through incorrect treatment of border trees and incorrect adjustments for leaning trees on nonlevel terrain.

For inventories requiring data other than variables correlated with tree basal area or height (such as species, growth, number of plants, and infestation rates by pests), the variable-radius method loses most of its advantages. These variables are not correlated to height or girth. A circular fixed-area plot with size proportional to stand density is recommended in continuous inventories for growth, number of plants, mortality, canopy cover, and stand table determination. Circular plots have less perimeter per area than rectangular plots and may be established by one person. However, large circular plots are more likely to have border bias because the perimeter of the plot is difficult to mark clearly.

Strip cruises are used heavily in tropical forests (Loetsch and others (1973). This type of sampling maximizes the area to be sampled relative to distance traveled, which is especially critical in dense forests. For strip cruising, it can be difficult to maintain proper strip width unless the width is narrow.

If ground vegetation surveys are to be repeated on permanent plots, rectangular quadrats are more efficient than other shapes and are well adapted to easy relocation. They also show more species variability than other shapes if placed across contours and are the best shape for mixed grasses and shrubs (Pechanec and Stewart 1940).

Circular plots may be desirable in herbaceous growth, where relocation is simple. The quicker plot delineation time of circular plots is especially advantageous when a large number of samples is being used, for example, in connection with timber surveys. Fixed-area circular plots have also been shown to be useful for total biomass estimation (Young 1977).

If efficiency is the main objective, particularly in surveys that will not be repeated, point or line sampling in connection with small quadrats is recommended.

Quadrats larger than 1 square meter should only be used in sparse vegetation.

A logical extension of strip cruising is line intercept sampling, in which the strip becomes a line with no area associated with the sample. A limitation is that samples are proportionate to size, which makes the method less efficient in estimating frequencies. This method should prove quite useful for short vegetation, such as pinyon juniper (Meeuwig and Budy 1981), and for dead vegetation on the ground, such as fuelwood (Brown 1974). It is also very efficient to determine crown canopy coverage of shrubs and basal area of herbaceous vegetation.

Potential border bias is more serious in range sampling than in timber sampling because it is generally more difficult to decide whether a bush or clump of grass is in or out of a plot than it is with a tree. Hence, for range conditions it may often be desirable to use a rigid sampling shape, such as a hoop or square, to minimize this potential bias.

A constant sampling unit size for all resources does not preclude subunits of varying sizes for measuring individual resource variables. Nested plots are particularly useful when they include smaller plots for detailed measurements, surrounded by one or more larger plots for measuring scarce or less frequently occurring variables.

Large fixed-area plots are commonly used to measure wildlife variables; a large set of small fixed-area plots for understory vegetation in timber stands; large fixed-area mapped plots for soils; variable-radius plots for timber variables; and a set of grip points for area classification, sample site, and plot location. These different plot configurations can readily be accommodated in any sampling design.

In multiresource inventories in which remote sensing sources of information are combined with ground sampling, it is likely that large circular plots would be used that are subsampled by angular count, small fixed-area, and possibly line intercept and rectangular plot samples (Schreuder 1982). These various subsamples would then concentrate on the specific variables of interest for which they are particularly suited. See Francis (1978 and 1982), Morris (1982), and Scott (1982) for detailed discussions of multiresource plot configurations.

Specialist support—Some multiresource inventories failed in the past because the users did not understand or support the new system (W. Peterson 1984). For least resistance, the integrated system must build upon existing methods and represent minimal change (Marita 1984). Existing procedures are those used in the past that are effective and still acceptable to the present users of such information (Rudis and others 1984).

Support of resource specialists may be gained if they are involved in the design and analysis of the inventory. Multiresource inventories should be designed with minimum functional ownership. All elements on a site should be recorded in terms of physical attributes. Each specialist would then classify or interpret these attributes to meet their individual needs. Successful integration is measured through the usage of the data and the enhancement of procedures through contributions from the specialists involved (Teply 1984).

Temporal Integration

Resource inventories initially provide only baseline data. If maintained overtime, inventories can provide trend data and eventually validation of predictions and assumptions. Inventories that are designed to provide information about changes or trends in land use or the resource base are integrated temporally (fig. 9). These inventories are the foundations for monitoring, which serves to determine if planning objectives are being met, to validate resource projections, and to detect unplanned changes in the resource base.

Change can most easily be monitored and trends established through successive or serial inventories. These inventories may also attempt to explain the causes of the changes that could affect the productivity of the lands and resources in the future. Growth and natural mortality, effects of management treatments, dramatic natural events, land exchanges, and the success of regeneration are the components we normally monitor through temporal inventories (Hasse and Robar 1983).

Needs and Requirements—The methods used to monitor and evaluate the consequences of activities resulting from planning and management activities must be consistent with those used to initially gather the data and information. Information needed for monitoring and subsequent evaluation should be considered during the development of land and resource

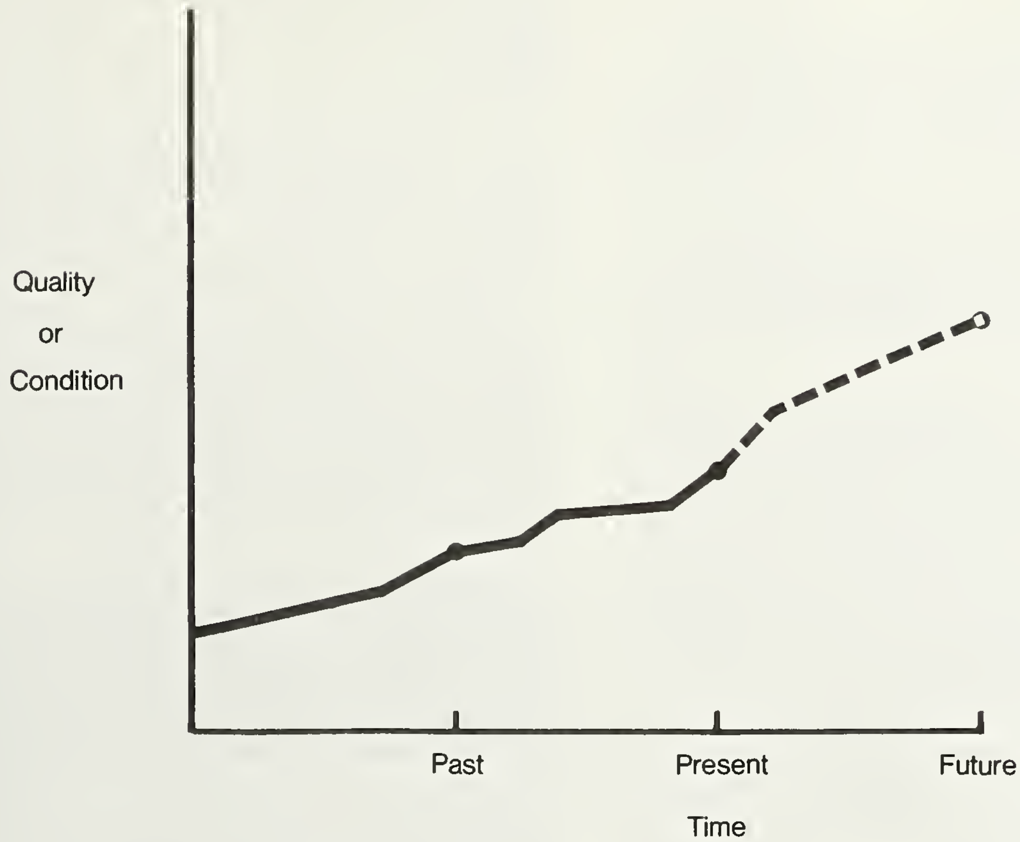

Figure 9—*Temporal integration requires measuring the same variables at the same location over time to observe changes and thus predict trends.*

management plans regardless of the decision level. Sample designs should be rigorous enough to achieve a certain measure of precision and accuracy in the estimates (Croze 1983). The units of measure used to estimate output effects must be the same as those stated in the objective of the inventory and management plans.

In selecting items to be monitored, the accuracy with which an output or effect can be measured as compared to the maximum range of changes that can result from management must be considered. The expected range of resource outputs or effects must be equal to or greater than the standard deviation in order for a change to be detected.

Haug (1983) recommends that attributes should be significant ecologically or have importance as a natural resource and would be affected by proposed activities. They should be identifiable, observable, and available during baseline and monitoring studies, and should be quantifiable by methods presently available and consistent with experimental design guidelines and statistical analysis requirements. The attributes should also be cost effective to measure (that is, the level of effort and cost necessary to sample the parameter should be commensurate with projected impacts).

Special Problems and Considerations — Identifying information requirements is a major problem in developing successive integrated inventories, for planners need to identify not only current information that is needed, but also information that might be needed in the future because of changing management issues. Changes in utilization standards, advances in measurement techniques, and requirements for increased precision for variables of interest all need to be considered.

The move toward complete tree utilization is an example of change in utilization standards that is currently under way. Total tree weight is replacing board foot and cubic foot volume as the variable of interest. Total tree height is an independent variable in the total tree weight equations being developed, and may, therefore, be required in current inventories along with the conventional merchantable height measurements.

A second problem is timing — when and how often should the resource be measured? When multiresource inventories are involved timing can be a major problem, especially when the attributes of interest change at different rates. For example, data collected on timber resources may be valid for 10 years, whereas information on range resources may be valid only for 2 years, Some resource information, such as that for soils or topography, may not change at all.

A third problem is in sample designs. How can bias be avoided or recognized in the selection of locations for remeasurements, and how can valid estimates of the current situation and of changes that have occurred since the last inventory be obtained?

A fourth problem area is that of maintaining records and documents of procedures used on the first occasion through to the measurement on the second and third occasions, and so forth. All too often, inventories are regarded as one-time special projects rather than ongoing processes (Dulin 1982). Changes in administration or direction, alteration in the schedule or timing of the inventory project, and the recalling of people and resources originally assigned to the project may weaken the reinventory effort (Caballero-Deloya 1982). Consequently, records tend to get lost, and the viability or reliability of the data erodes over time.

A final problem is identifying what has really changed and what has not. Changes in standard, techniques, improper sampling frequency, and lack of followup analysis can yield improper interpretations (Lund 1983).

Recommendations — The following are options and recommendations for identifying information needs for temporal integration, for determining frequency of reinventory and updating, and for inventory design.

Information needs — As with the other forms of integration, an information needs assessment is required for temporal integration. With temporal integration, however, we must anticipate future needs and yet be able to relate those needs to information that has been collected in the past.

Observations on the successive occasions should be based upon the same measurement instructions, techniques, and perhaps equipment that were used on the first occasion. In addition it is efficient to measure and record only those variables that should show a change (Learmonth 1967). Planners need to concentrate on identifying the variables that are likely to change and measure those variables in continuous units to meet possible future needs.

Some variables cannot be remeasured at the same location, and new variables might need to be considered. Soils, for example, cannot be remeasured if destructive sampling such as the digging of a soils pit was used on the first occasion. Measurements of sediment in a river or of vegetation production may be alternative ways of gathering subsequent soils information.

Taking photographs at the time of inventory may also help to link the past with the future when elements of change cannot be readily anticipated (Benson 1983). Photographs present, at low cost, many features or elements that are difficult to convey in numbers or words and may provide the only available index to features that were not of interest at the time of inventory.

Techniques have been developed that provide consistent, rigorous, and quantifiable ways to interpret human perceptions and judgments in evaluating photographs. Benson (1983) and Rogers, Turner, and Malde (1983) provide excellent information on taking and documenting photographs.

The collection of specimens (plant and animal, tissues, soil, water and air samples) and storing these specimen banks is an alternative when the components of change cannot be anticipated. This technique is particularly useful when monitoring for the effects of toxic chemicals in the environment (Lewis 1983).

Frequency and updating—The frequency of monitoring or reinventory may be based on an elapsed time (for example, every 10 years) or triggered by the occurrence of known changes in the resource base (Milazzo 1982). The eruption of Mount St. Helens, for example, was an event that called for a reinventory of the surrounding area to measure the changes that occurred.

It is cost efficient to concentrate sampling efforts in areas of known, anticipated, or suspected change and to use updating or modeling procedures in areas of little or no change. Remote sensing and data bases can be evaluated to determine when significant changes have occurred to warrant reinventory.

The frequency of reinventories for multiresources may be based upon the frequency of the resource that changes most slowly. Sampling rates based upon fluctuations of the most rapidly changing variables would result in redundant and unnecessary data in the more slowly changing variables (Herrington and Bertolin 1974).

Computers simulation models offer a means to update inventories and thus increase the timespan between remeasurement at low cost, high speed, and with no errors of data transfer. Such models are flexible and permit some mistakes to be made without lasting harm.

Models for monitoring programs should have the following characteristics (Hirst 1983):

- Simple—underlying assumptions are kept simple and the hypothesized relationships between the monitored popuation and causal factors are restricted to those which can be simultaneously measured and easily interpreted.

- Empirical—populations at different points in time are functionally related to the causal factors in a way that permits extrapolation but does not necessarily convey information as to why relationships exist.

- Dynamic—easily changed.

- Discrete.

- Analytical—parameters of the functional relationships are estimated by mathematical solution or simulation.

The North Central Forest Inventory and Analysis Unit uses a design incorporating modeling and sampling with partial replacement (SPR). This design is applicable when a number of previously measured plots that can be projected by a growth model or processor are available. These plots are first classified into two classes, disturbed and undisturbed, by interpretation of aerial photographs. *Disturbed* plots are those plots in which some event has taken place that the growth processor cannot simulate. These plots are handled separately. Estimates of change for the disturbed class are made using field investigations. *Undisturbed* plots are projected forward to the present. Some undisturbed plots are remeasured as well as projected to produce a regression estimate for the undisturbed class. The estimate is then applied to the other undisturbed plots. Two estimates are produced: a projected estimate of current conditions and change for all undisturbed plots and an observed estimate of current conditions and change for those plots that were actually remeasured (both disturbed and undisturbed). These values are combined to produce a single estimate. New plots may also be added to improve the estimate and to ensure that enough plots will be available for the next inventory so that the procedure can be repeated (Hahn 1984).

The primary disadvantage of using models may lie in the difference that can exist between the simulated and the actual situation, a factor that increases over time (Mathis and Hetherington 1981). Model-based sampling is recommended for short-term periods and situations for which there are only a few variables of interest.

Adjustments in the resource base should be based on:

- Unbiased, statistically valid projections.

• Changes in the data base resulting from treatments, land exchanges, etc., reported to and stored in the appropriate information systems.

• Catastrophes of sufficient severity to change the productivity and suitability of the inventory unit.

• Growth and mortality since the last inventory.

If updating procedures are used, users should be informed as to the exact nature and origins of the data presented. Users are better served by unchanged data from the most recent individual inventories (with dates provided) than by data that are updated by projection techniques to a common point in time (Oswald 1983). If a common point in time is used, the data should be labeled as projections.

Design—Design options depend upon past inventories, the choice of permanent or temporary plots, and the use of replacement or nonreplacement sampling.

(1) Availability of past inventories

If inventories have been established in the past, one should consider using the old plots as a basis for monitoring. The past inventory and the remeasurement provide estimates of changes and trends. However, the older system must be evaluated to see if it meets present and anticipated future needs.

(2) Permanent versus temporary plots

There are two choices for plots on which to base observations. One is to establish a set of permanent plots and monitor all or a portion of the permanent plots (sampling with partial replacement if a large area is involved) over time. The second is to establish temporary plots, and through observations and measurement, estimate what changes have occurred (Matern 1980). Both techniques examine what has happened in the past and use that information to project what the situation will be in the future.

Temporary plots have the advantage of generally costing less to establish (do not have to document location or relocate boundaries), have less chance of disturbing existing vegetation (repeated visits may affect growth, especially if using destructive sampling), and plots can be located selectively in areas of current economic importance.

It's generally agreed, however, that permanently established plots can yield the most useful information for monitoring change and predicting trends (Cunia 1978). According to Hagglund and Bengtsson (1980), permanent plots provide a) greater efficiency in estimating changes in land use and in the state of the resources; b) precise information on the components of change in growth, treatments, increments, and change in land use class areas; c) sound data for long-term forecasts of resource yield; d) a sound base to validate assumptions of long-term forecasts; e) overall lower inventory costs (variables that change slowly over time, such as tree diameter on sites with low productivity, require minimum observations of measurements on successive inventories (MacLean 1981) and variables that generally do not change, such as aspect, slope, and elevation, need to be recorded only at time of establishment); and f) value for research as part of a planned systematic monitoring system of the environment.

Generally, permanent plots will have a lower cost for a specified standard error when a measurement of change is the objective. Although permanent plots may be more expensive to establish, consideration of the overall cost of an inventory may cause the difference to be nonsignificant. With permanent plots, observations made on the second occasion should be more correct than on the first. Usually crews have more time available on a remeasurement effort and in theory can take more careful measurements. In addition, the crews should have the data from the previous inventory or occasion so that they can identify and resolve discrepancies while on the plot.

Curtis (1983) provides excellent instructions on establishing and maintaining plots for tree silvicultural and yield research.

(3) Replacement versus nonreplacement sampling

There are two primary possibilities for successive inventories: sampling with partial replacement and sampling with complete remeasurement of plots or sample units. By sampling with partial replacement (SPR), also called *sampling on successive occasions* or *rotation sampling for a time series,* units are sampled over time with the definite intent to replace part of the units sampled at earlier times. The concepts of SPR are relevant in many situations where the inventory designer wishes to utilize new concepts in population sampling (Barnard 1984).

The advantages of SPR:

- SPR sampling can be highly efficient in estimating population means at a given time by utilizing information from earlier surveys combined with new information.

- Knowledge of plot locations could imperil the representativeness of permanent plots. New sampling units can enter the sample, which ensures that the current sample is representative of the current population.

- Reinventories based on repeated examinations of the same locations may result in the same estimates of deviations about the true population total (Stage and Alley 1972). SPR provides an opportunity to obtain different estimates.

The disadvantages of SPR:

- SPR sampling is quite complex. Even when dealing with the simple estimators so far considered and the simple designs, estimation theory is cumbersome and requires many assumptions such as known correlations. Even here a fully developed theory is not yet available.

- Estimation theory for complex designs and estimators is likely to be very complicated.

- Estimating likelihood functions or other more complete summarizations of data is likely to be difficult.

- Implementing and visualizing complex sampling designs may be difficult. The use of complex designs is likely as remote sensing technology improves and ground sampling becomes more costly.

- The complexity in design and estimation makes errors in implementation more likely than with simpler strategies.

SPR is appropriate when there are dual inventory objectives such as estimating current timber volume and growth. If only an estimate of growth is needed, all permanent plots should be remeasured.

Complete remeasurement sampling is recommended when there is a need to develop trend prediction equations or to monitor environmental impacts of resource management treatments. The resulting data provide a tremendous research base for production models (Flewelling 1982).

Information from the sample locations should remain representative of the population of interest. This can be ensured by keeping the sample locations inconspicuous, by not allowing destructive sampling on the plots, and by keepling visits to the ground locations to a minimum. At every remeasurement, a comparsion should be made between the old and new data to determine if there is any evidence of nonrepresentativeness. Some of this may be determined through interpretation of remote sensing imagery prior to field investigations. If plots are no longer representative, SPR or complete replacement should be considered.

Maintenance—The most reliable and also the most expensive inventory method is a combination of temporary and permanent or semipermanent sample plots and an organization that guarantees repeated measurements at intervals according to accepted plans.

In order to be successful, this kind of system should be organized and financed on a continuous basis. Changing values and aims in management and financial policy, which change inventory methods and observed characteristics, jeopardize the efforts to maintain reliable and long-term forecast balance information (Kuusela 1983). Inventories integrated over time must be viewed, supported, and funded on a continuous basis if they are to be successful.

Complete documentation is required and records must be maintained for each successive step. Inventory plans must be kept as well as the data.

Anyone who establishes a permanent plot should recognize that he hereby assumes responsibility for furnishing future workers with a complete picture of conditions on the plot at the time of its establishment. Not only must each plot be properly marked and all measures be in perfect order, but all notes and records must be full and complete. Otherwise, the plots may fail to yield the desired results and those who in later years become responsible for their care and analysis of the data may be led into serious mistakes. USDA, Forest Service 1935

Interpretation—Changes should be measured, analyzed, and reported on at the survey area level rather than at the sample unit level (Oswald 1983). After successive inventories are completed, the data need to be carefully analyzed to determine the significance of perceived changes. In some instances, what are perceived as changes in the resource may actually be due to changes in the inventory (e.g., standards, definitions, techniques).

To properly interpret the results, a) one must determine which concurrent differences, if any, have occurred during the period between inventories; b) if there are differences one must determine their impact on the previous and/or current resource estimates; and c) if the impact is significant, one must adjust the previous or current estimates so that they can be compared (Powell and Cost 1983).

Adjustments may be made by a) accepting the measurements on the first occasion and "predicting" new measurements on the second; b) assuming the measurements on the second occasion are correct and recalculating the statistics on the first occasion; or c) using the data from both measurements, computing and using an average.

In most circumstances, the second alternative is preferred. It is also possible to check the measurements on the second occasion to make sure the error had not occurred on the remeasurement.

To minimize the problem in future inventories, Van Sickle (1983) recommends a) recording actual measurements rather than assigned class for interval values; b) determining and maintaining a set of fundamental resource attributes; making comparisons for change only on information items that are directly comparable (estimates from earlier inventories may need to be recomputed or reclassified for comparison); taking appropriate care to establish the time interval between inventories; and e) carefully evaluating the perceived need to change definitions and standards against the possible loss of comparability.

Figure 10 outlines useful steps for moving from single purpose inventories to those that are fully integrated. The principles of integration are the foundation. Standard outputs, inputs, definitions, and data bases are developed so that all field units are gathering the same type of data. Common locations are specified to define responsibilities and to provide common sampling units. Multiresource core data required by the next higher echelon indicate the minimum data to be collected. Design, scheduling, and budgeting coordination provides efficiency in the inventory program and continuity for monitoring. Lastly standard measurement rules are specified so that all involved have a common understanding as to what the resulting data mean. At the earlier stages of development, involvement of the decisionmakers is essential. At the later stages, the work of the inventory specialists comes into play. Both the specialists and the decisionmakers must be involved in planning, implementing and maintaining the inventory program.

Successful planning of an integrated inventory requires the agreement of those seeking the integration, such as agencies, line organizations, and resource specialists, on supporting the integration effort, the objectives for the inventory, and an inventory plan. The information needs, inventory objectives, and design options should be discussed by all concerned. Inconsistencies between users' needs must be resolved. Duplication of effort, information gaps, and inconsistencies in information are avoided by such planning before the implementation of an inventory (Kemph and Lopez 1978).

Coordination and communication should include the specification of the inventory data and personnel requirements, funding, and time constraints for conducting the inventory, distribution of responsibilities, and the analyses and reporting of results from investments.

The basic steps in designing and conducting an inventory are 1) determining what information is needed, 2) determining what usable information is already available, 3) developing a plan for obtaining the information that is not available, 4) obtaining support, 5) implementing quality control, and 6) maintaining systems (fig. 11).

The design effort should have enough detail to assure that the inventory manager can keep track of the progress, time, budget, resources and results and to assure a

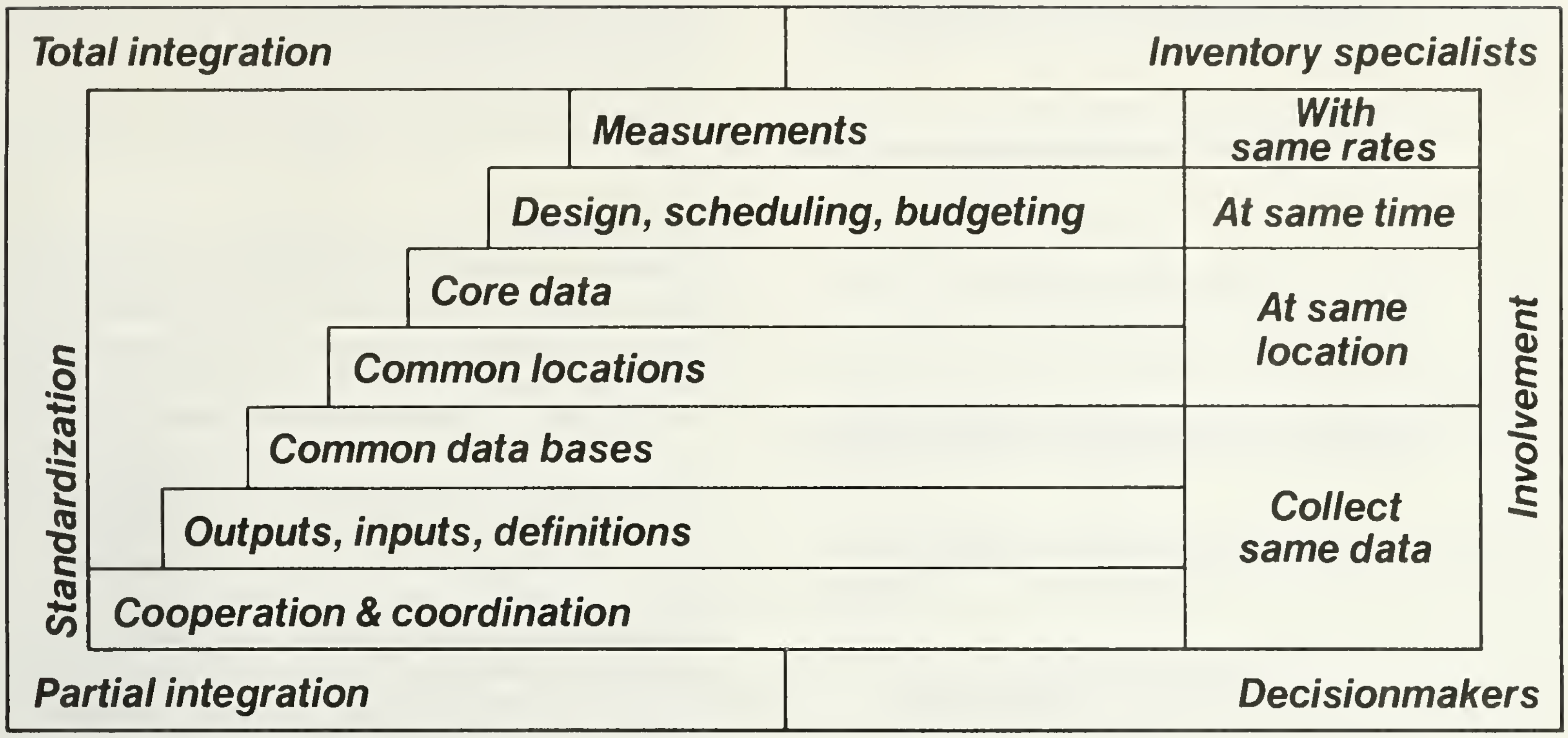

Figure 10—*Steps leading toward integration.*

smooth transition of the inventory if shifts in key personnel occur (Larson and others 1984).

Information Needs and Availability

Identification of Information Needs—The following questions need to be addressed: a) what are the issues and concerns? b) what management decisions are needed? c) what decisions need to be made about the resources? d) what is the relative impact or risk (cost) of an incorrect decision? e) what is the area (survey or inventory unit) to which the decisions will apply? and f) what are the monitoring requirements?

To answer these questions, inventory planners must understand the decisionmaking process, identify who makes the decisions, identify other parties potentially involved or affected by the decisionmaking process and involve these people in identifying information needs (States 1978). Information needs may include availability of quantitative data on location, amount of resources by kind, dynamics of the resource such as increment and loss, and socioeconomic value.

The second step is to identify the information required to address the issues and solve the problems. Required tables, maps, and report forms are developed and data elements are identified to provide the information. These should be approved by the decisionmakers. The specification of output products not only helps identify information needs, but also is useful for explaining to potential users the extent to which consistent information is available (Goforth 1984).

The variables for inventory must be clearly identified. For example, a request for "data on potential bird nesting sites" would be far more confusing to inventory specialists than would a request for "the number of trees or snags per hectare with a diameter at breast height greater than 25 centimeters and a total height greater than 5 meters."

In addition to specifying the type of data needed, the required precision and timeliness (currency and frequency) should also be specified. Using the example above, one might need to know the number of snags per acre ± 5 percent every 10 years.

Locating Existing Information—Planners should make maximum use of existing information to minimize in-

Figure 11—*Inventory development process.*

ventory costs. Some guidelines for general information economics (Rose and others 1981) are to:

• Seek only information related to some output objective.

• Avoid generating or collecting more information than is needed.

• Open lines of communications and spend some time exploring what information is already available.

• Consider the level of confidence in available information.

Existing information can take any form including published reports, maps, imagery files, data bases, and so forth. Trade statistics, records of treatments or harvest, and mapping updates are sources of information on changes and trends. Often, however, inventory planners ignore existing information (Collins 1984).

Although existing information is often abundant, it may be diverse, scattered, and difficult to locate. Sources of information include land administering agencies, survey and remote sensing centers, agricultural statistics services, land-use institutes, universities and research organizations, industries, consulting firms, and professional societies. Existing information tends to be abundant for specific local situations rather than broad areas.

Some existing information may be difficult to obtain. Those needing the information may not know that a source exists. Inventories may have been conducted for socioeconomic, political, legal, or ecological concerns. Sometimes, even if the source is known, the data may not be published or accessible to the general public.

Existing information may vary in its reliability and utility. Different sources may use different standards, definitions, and codes. Estimates may be based on crude guesses or on highly sophisticated sampling strategies. Existing information from different sources may also conflict.

Often existing information (i.e., maps, tabular summaries, attainment reports, reviews) is not arranged according to a needed area classification system. Summary statistics available may be developed from very different classification systems. In this situation, it may be more desirable to use the plot records, particularly if the location of each plot is known. Without the plot locations and the plot information, map or tabular information produced by two or more efforts can only be combined for new uses with great difficulty (Lanly 1976).

Map updates may reflect actual changes or corrections. Boundaries of two separate mapping operations over common terrain may not coincide unless the resources being mapped are directly related, the scales are the same, the survey intensity levels are the same, and the differentiating criteria for map units are common to both surveys (Valentine 1981).

Trade statistics compiled from questionnaires exhibit considerable bias. At regional or national levels, such estimates are rough, but because the bias and degree of incompleteness do not vary greatly from year to year, these data may reflect prevailing trends quite accurately and new developments almost immediately (Schmid-Haas 1983). Records of treatments or harvests are usually recorded for only part of the population, and such records may not be available for regional or national use.

Evaluating Existing Information—Existing information needs careful evaluation. Useful criteria for this process, modified from Lund and Schreuder (1980) and Milton (1982), are given in this subsection.

(1) Adequate documentation.

- What is the source(s) of the original data?
- What is the scale(s) or intensity at which the original data were collected?
- When were the data collected and what methods were used?
- Agency inventory programs, planned or ongoing, that relate to the data.
- What are the significance or importance of the data to the source agency?
- What are the limitations of the data as perceived by the originator and users?
- Who is a contact person for further information?

(2) Ease of interpretation and use for intended purposes.

- Are data in a form such that potential users can readily understand? Are there any training and expertise prerequisites to use data?
- Can the data be used without special reinterpretations?
- Are the variables defined and used in the same way as what is currently required?
- Are the data still valid?
- Were the sample units readily identifiable?
- Were the sample selection techniques statistically valid so that the estimators of sampling errors can be calculated to determine the degree of reliability of the results?
- Were the standards the same as what are currently needed?
- Are the area controls the same?
- Are there gaps or overlaps in the areas of concern?
- Were there adequate quality control checks applied in the data collection, compilation, and summary processes?

(3) Cost efficiency of using existing data.

- What would be the cost of collecting new data? If existing data are flexible or basic enough to be used, what are the potential savings as opposed to collecting new data?
- Are the data enduring enough to be valid for the timespan required?
- What is the likely cost of repeating the inventory if the data collected are inadequate?

If the criteria cannot be satisfied, data should not be used or combined unless qualified by statements or footnotes indicating where deviations occur. Even though some existing information may not serve any immediate need, it may be useful for validating new data.

Data Acquisition

Setting Objectives—Data are collected efficiently when the objectives are clearly defined. Objectives should be derived during the face-to-face meetings between designers and users.

Failure to define objectives can result in collection of the wrong kind of data or too much or too little of the right data. It may be false economy to conduct an inventory for only one use objective. Experience has shown that areas inventoried with only one or two use objectives in mind have often had to be inventoried again to obtain additional data. In each of these cases, additional data could easily have been collected during the original inventory if other needs had been identified.

For multiresource inventories, the objectives should be uncoupled from traditional strategies, such as, for example, timber production, range, and wildlife (Bie and Lamp 1983). Lanly (1976) offers the following suggestions when establishing the objectives for an inventory:

a. The objective of an inventory should reflect the level and scope of the planning under consideration, the nature and size of the unit of management, and the stage to be reached in the decisionmaking process. At the same time, the proposed inventory must be viewed as to its place in a broader scheme of information needs. For example, an inventory being taken for an industrial investment should be seen in the more general context of a forest industrialization policy extending beyond the physical limits of the particular site under consideration. The policy for resource development should be coherent at all levels. This requires that adequate information for decisionmaking be available at each level.

b. Seldom can a single inventory serve all objectives at the same time or give answers to all questions that might be asked. If there are too many objectives to be satisfied, the data collected and the intensity of sampling could become so detailed that the objectives could not be satisfied at a reasonable cost. Hence, in many cases more than one inventory will be required to realistically meet all the proposed objectives.

c. The priorities of the objectives should be established. If funds are limited, then a list of priorities should be agreed upon. An inventory can be designed to be efficient for the most important parameters but may not be efficient for others.

d. It is important to get the right mix of people involved in establishing the objectives. Integrated inventories that have failed in the past did so because of failure to get together those responsible for the inventory, the users and the decisionmakers. Users and designers should jointly develop specifications, where applicable, for ground control, photography, photo interpretation, field measurements, data records, field checking procedures, specific computer programs, and computer analysis (including the format of tables, errors of estimates, and final report format), plus an allowance for flexibility in the entire system. The specification must clearly state the required accuracy for all phases of the inventory. These are the standards against which the inventory will be judged at a later date (Tyron and others 1983).

Typical questions that need to be asked when specifying inventory objectives include:

- What decisions are going to be made on the basis of the inventory?
- What information is needed to make the decision?
- What impact will errors in the information have on the decisions being made?
- What impact will incorrect decisions have on the resource?
- What impact will incorrect decisions have on the decisionmaker?
- What are costs of collecting various sets of data?
- How must the data be analyzed to provide the information in a usable form?
- How are the responsibilities and costs shared?
- How are the results to be presented?

The objective statement should indicate the primary attributes to be estimated, any limitations on the attributes, the precision required for decisionmaking, and the survey area for which the estimates will apply. An example of a complete objective inventory statement is, "To estimate the total gross cubic meter volume (live and dead) of trees with a d.b.h. of 2 centimeters or more in the Dead Horse Planning Unit. This estimate should be within ± 20 percent of the true volume with 66 percent confidence."

While establishing the inventory objectives, it is also desirable to bring new inventory techniques to the attention of users so that they can express preference based on cost and amount of data required.

Users should participate equally in inventory planning and in some instances, the fieldwork. This builds their confidence in the data. Knowledge of the land and a thorough understanding of the inventory system is needed on the part of the decisionmaker (Tyron and others 1983). Lastly, the bulk of the field data collection requirements should be within the skill levels of a good technician.

In addition to the specifications of the inventory objectives, the use of remote sensing, the selection of the survey area, design constraints, plot configurations, and sample intensity need to be considered, tested, and decisions documented in an inventory plan.

Use of Remote Sensing—The extent to which remote sensing can be used depends on the information sought, the ability and experience of the interpreter, the equipment used, the accuracy or precision required, the film type, and the scale of imagery used (Paine 1981). Table 4 lists some typically needed parameters of vegetation and landform and their detectability and measurability on various kinds of aerial photography.

Other information on vegetation can be predicted or computed indirectly from easily interpreted variables. For example, stand volumes may be predicted from stand height and crown closure measured on aerial photographs (Moessner and Jensen 1951, Spurr 1960, Bonnor 1968). Variables such as site index, yield capability, trees per acre, basal area per acre, stand diameter, stand age, and stocking have also been predicted with some limited success (Lund 1974a).

Remote sensing is used to classify or stratify the cover/land use classes, reducing variation and increasing sampling efficiency in multilevel sampling designs. Depending on the ground resolution of the data and sensors used, classification may range from very broad stratification such as the level one (i.e., forest land, range land, agricultural land) classification of Anderson and others (1976) to identification and enumeration of individual vegetation species, age classes, and cover classes. Mapped units or sampled points within these strata are then more closely examined through multiphase sampling with small-scale, medium-scale, and large-scale aerial photography or finally with a field visit.

Remote sensing is also used to define survey and sampling units through mapping processes and in some cases may be used to expand data by extrapolation to nonsampled areas (Garratt and others 1982, Brickell 1984). Inventories that have used a combination of remote sensing methods with reduced ground sampling intensity have proven to be economical and efficient (Hegg and others 1981, Miller and Meyer 1981).

If permanent plots are established during an initial inventory, then remote sensing can be used to monitor and update the resource land base. Schmid-Haas (1981) utilizes a grid of permanently located photo interpretation points to monitor area changes. These are restratified as changes are detected and are interpreted to provide area and, in some cases, volume estimates.

Satellite-acquired imagery, in digital form, is particularly attractive for establishing a base for integrated inventories, because of its wide area coverage. With some work, data can be used for direct tabulation of area, stratification, extension of selection probabilities, and definition of populations. The repetitive coverage and relative ease of multidate registration of satellite imagery also makes it suitable as a screen for sampling with partial replacement and use of projection modeling (Peterson and others 1982).

The most frequently used space platforms are Landsat and weather satellites with an advanced very high resolution radiometer (AVHRR). For detailed discussions on applications of these satellites see Williams and Miller (1979), Treadwell and Buursink (1981), Tueller (1982), Thomas and Colwell (1982), and Justice (1983).

Potential users of remote sensing must be knowledgeable of the characteristics, capabilities, and limitation of the sensors as well as methods for processing and analyzing the data from each of these systems. For a more indepth discussion on the potentials of remote sensing see Aldrich (1979a, 1979b, 1981), Baltaxe (1980), and Myhre (1982).

Table 4—*Ground resolution, photographic scale, and film type required to detect or measure basic resource parameters*

Parameter	Required ground resolution(m)	Preferred[1] film type	Smallest scale Detection	Smallest scale Measurement
Vegetation species composition	0.1	CIR	1:3,200	1:1,600
		Color	1:5,000	1:2,500
Number of layers	0.3	CIR	1:12,000	1:6,400
		Color	1:20,000	1:9,600
Stand size	0.3	BW	1:20,000	1:9,600
Understory enclosure	0.3	BW Color	1:20,000	1:9,600
		CIR	1:20,000	1:6,400
Ground cover	0.3	Color	1:20,000	1:9,600
Tree height	0.3	BW	1:20,000	1:9,600
Crown diameter	0.3	BW	1:20,000	1:9,600
Crown area	0.3	BW	1:20,000	1:9,600
Number of trees	0.3	BW	1:20,000	1:9,600
Dead trees	0.3	CIR	1:20,000	1:6,400
Uniformity of cover	1.0	BW	1:64,000	1:32,000
Cover type	3.0	CIR	1:125,000	1:92,000
Size of cover	3.0	CIR	1:125,000	1:92,000
		BW	1:125,000	1:125,000
Shape of cover type	3.0	CIR	1:125,000	1:92,000
		BW	1:125,000	1:125,000
Cover type change (proximity)	3.0	CIR	1:125,000	1:92,000
		BW	1:125,000	1:125,000
Landform	3.0	CIR	1:125,000	1:92,000
Exposure	3.0	BW	1:125,000	1:125,000
Overstory closure	3.0	BW	1:125,000	1:125,000
Cover class area	3.0	BW	1:125,000	1:125,000
Distance to water	3.0	BW	1:125,000	1:125,000
Spectral ratios	5.0	CIR	1:125,000	1:125,000

[1]BW = panchromatic, IR = infrared. Color = normal color, CIR = color infrared.

Data from Aldrich (1979a, b, and 1981).

Inventory Designs—There are many examples of integrated inventory designs including multilocation (Van Hooser and Green 1981), multilevel (Costello and Lund 1979), multiresource (Lund and Kniesel 1975; Lund 1979a and 1979b; McClure 1979; McClure, Cost, and Knight 1979), and inventories for monitoring change and trends (Cunia 1974, Bell and Atterbury 1983).

In order of restrictiveness, integrated inventories should be designed to a) permit different sampling intensities in both time and space; b) permit poststratification; c) allow for efficient use of covariate information; d) accomodate new statistical standards in estimation; and e) provide compatible information with other available information.

Because of the costs involved, data collected in an inventory must be durable and usable over considerable timespans. Unfortunately, management needs change continuously, and design that is efficient at one time may not contain information that satisfies needs over the long term.

The best design, under these circumstances, is one that is simple in concept and implementation and permits some expansion on data collected (Reimer 1982). A one-stage systematic sample with a random start is an example of such a design.

The design chosen depends on the objectives of the inventory, the detail and precision required, and the availability of previous knowledge, equipment, materials, workers, and funds. Selection of the design should be based on its ability to provide the needed information at the least cost and risk of providing poor data.

Selection of Survey Area and Sample Units—In planning the inventory, designers should give as much emphasis to the delineation of the inventory or survey unit as to the estimations that will be obtained within the unit. Delineated areas are usually either homogeneous with respect to some resource characteristics or are of suitable size or makeup for optimum management (including legal and economic aspects) or for updating. Updating and monitoring require that the survey area be kept unchanged from inventory to inventory. This criterion may lead toward geographically distinct borderlines surrounding a fairly large survey area with substantial internal variation (Poso 1983).

Plots are frequently allocated within the survey area according to a systematic design. Some inventories use mapped "stands" or other homogeneous polygons as the plot allocation or sample units and emphasize sampling to describe the individual "stands." Results for the survey area are summarized by aggregating the plot information (Ek 1983). Table 5, adapted from Nelson (1984), lists some advantages and disadvantages of various types of sampling units.

Plot size and shape should usually be considered simultaneously in inventories, particularly in heterogeneous populations. Two samples with the same plot size but with different shapes may produce substantially different estimates of the variance.

Sample Intensity—The number of plots or sample units is related to plot configuration, but for practical reasons it should be considered as a separate item. In any sample strategy, the closeness of the sample estimates to the true population values will depend on the sampling design, the population variance, and the sample size. When selecting plots, it is more important to achieve an adequate number of plots than to aim at some predetermined sampling intensity, regardless of the population variability (Dawkins 1952). The sampling fraction is relatively unimportant for large populations. What matters is the sample size. For example, fifty 0.25-hectare sample plots may give estimates of almost equal precision for populations of 50,000 and 100,000 ha.

In selecting the number of plots to be sampled, there must always be a compromise between acceptable precision and the need to keep fieldwork and expense to a reasonable minimum. Increasing the value of information obtained from each plot by selecting a larger plot size makes it possible to reduce the number of plots required to achieve a given level of precision (Synnott 1979). Measurement time per plot will be greater, however. Where travel is difficult, as in remote mountainous areas, the question of travel time to plots assumes major importance (Husch and others 1972).

Scott (1982) recommends: observing as many sampling units per day as possible to avoid overhead costs; having field crews work as long a day as feasible; and, observing more than one subunit in each sample unit unless the mode of travel between sampling units is the same or within the sampling unit.

Testing—Prior to implementation, the entire inventory system must be tested. This is done to determine if, in fact, the system will provide the desired information and to measure the anticipated variation for use in determining the sample intensity (Kuusela 1981).

Trial runs should be done with inexperienced crews for a more realistic evaluation of costs and production rates (Whiting 1983).

Inventory Support

Once a plan has been developed, the next task is to obtain support. Resource inventory and monitoring strategy demands mastery of design, expectation, analysis, and acceptance by the establishment for a

Table 5—*Evaluation of possible common sample units*

Sample unit	Strengths	Weaknesses
Points	Good sampling design capability; minimal interresource conflict; lower skill level requirements; elaborate, large data base; good trend information.	Treatment of spatial character of resource minimal; applications tend to lack sensititivity to pattern of information needs.
Cells	Good sampling design possible, permits spatial display, minimal interresource coordination needed, stable over time.	Requires a geographic information system, cells may not reflect intricate resource pattern, synthesized integrated units may not be recognizable on the ground.
Timber stands	Widely used, well understood, large flexible data base system, focuses on primary resource for management activity.	Criteria for delineation changes geographically over time depending on many variable; excessive focus on sometimes controversial commodity resource.
Ecological types	Stable, reflect long-term opportunities, neutral units for competing resources; visible to land manager, allows variable sampling intensity.	High skill level required for delineation; criteria variable, may be subjective, not automated, lack complete coverage. Requires strong interresource coordination.
Overlay existing resource inventory maps	No interresource coordination required, logically clear, permits direct use of existing inventories.	High cost, duplication. Synthesized integrated units may not be recognizable on the ground.

long-term commitment to continuation of inventory monitoring program. The selling of an integrated inventory requires political and public relation skills, special knowledge of the needs of constituency interest groups and a broader understanding of the longer term problems and potentials of the resource (Warner 1983).

A successful integrated inventory depends on commitment by top management and support from below. The ability to tie inventory activities and budgets to plans and programs, and the development inventory analytical approaches that work across disciplinary, geographic, and organizational boundaries will help sell the system.

Administrative support is essential if an inventory is to be financed. When costs must be cut, expenses not directly tied to immediate production are logical starting points. The cost of an inventory, even though minuscule compared to the use of the data, is not generally considered a production expense, and the payoff from the inventory usually comes several years later. Inventory systems designed for minimum operating costs have a higher chance of being funded (Wakeley 1983). Top management will only invest in a system if it appears to be realistic and if it will result in substantial savings to the organization.

Administrators view inventories and the resulting information systems as communication, planning, and control tools. Field personnel are interested in inventory systems that simplify daily planning and recordkeeping. Other inventory specialists are concerned with the analytical capabilities and how a system can help them with their own set of responsibilities. Top management focuses on the cost of the system and is more concerned with the credibility of the results rather than technical applications.

Therefore, the proposed system must consider both the communications, politics, and resources in question and at the same time fit into the agency's overall strategic picture. A system that eliminates or reduces communicational or procedural bottlenecks or solves frequent or ubiquitous problems stands the best chances for support (Knudson 1982).

Hirst (1983) suggests the following steps to obtain support for an inventory program:

- Anticipate organizational responses.

- Define the objectives of inventory program in terms of understanding or managing a resource and not in terms of the process or method to reach the management goal.

- Show the direct economic or scientific value of the inventory.

- Link the inventory program to a responsible group within the organization.

- Provide for a periodic review of the program to ensure credibility.

Some barriers to management accepting an integrated inventory system are: 1) apprehension that quality data may weaken or contradict previous or current assumptions; 2) perceived higher costs for additional inventory activities; 3) resistance to change in tradition; 4) perceived disruption to current levels of authority or control; 5) potential challenge to existing communication networks.

Parker (1983) suggests the following steps to remove the barriers:

- Coordinate with receptive people first to set an example.

- Identify how assumptions based on professional judgment can be verified and strengthened with supportive data or modified to produce a more effective program.

- Demonstrate to top management that supportive data are more defensible than professional judgment.

- Demonstrate that unified inventory and monitoring actions will reduce time necessary to obtain and evaluate data.

- Display benefits of increased management effectiveness and ability to identify undesirable trends quickly.

- Explain the supportive nature of integrated data to management authority.

- Demonstrate how integrated data will support communication effectively through upgrading of interdisciplinary awareness of resource coordinates.

- Identify how inventory and monitoring actions will assist in attaining individual and program goals.

- Use a high degree of managerial participation in establishing the criteria for the information system and maximizing the involvement of the people who will actually be using the data.

Munro (1983) offers additional advice for implementing a new system:

- Make sure recommended system represents a production environment, not research or demonstration.

- Don't underestimate implementation time. Plan for unanticipated costs associated with delays due to startup problems, learning curves, and actual production time.

- Establish specific systems support development and training responsibilities.

- Be careful not to generate demand until the system is capable of producing results. User expectations tend to outstrip initial system capabilities and available data.

- Budgets should realistically address realities of data base construction, processing systems installation, and staff support.

Inventory Organization and Staffing

Organization—For small organizations a permanent, centralized coordinating unit is desirable for developing, implementing, and maintaining integrated inventories. The unit can establish standards and quality control where none exist. It can combine existing activities into mutually compatible information networks. It can underwrite environmental assessments to produce information where there are gaps.

A central unit can bring groups of experts together to formulate approaches to environmental problems. It can enlist the talent and relevant program components of special agencies to tackle particular problems. The unit can support research and development required to devise and test new techniques. Lastly, a central unit can design and find funds for inventory and monitoring projects (Croze 1983).

The central coordination unit would therefore serve four functions: a quantitative arm, a think tank, an information center, and a common forum for otherwise disparate ecologies and environments (Hennemuth and Patil 1983).

A centralized unit is easy and less expensive to staff, equip, train, supervise, and control. More sophisticated systems can be used, and there is more control of inputs and outputs (Wakeley 1983).

For large organizations, centralized staff may invariably duplicate or overlay local data collection responsibilities. This could lead to "our data" versus "their data" confrontations. People at lower echelons may view the central unit as an authoritarian bully.

Decentralized organization provides more inventiveness and local acceptance of the resulting data, but it is more difficult to ensure quality control and to enforce inventory scheduling (Grainger 1983). A solution is to have shared responsibilities between a central unit and the lower echelons. Standards should be established by the central unit and reviewed approved by the field. The actual control and inventory could be carried out by the local manager.

Van Hooser and others (1984) recommend that an inventory coordination be established at each level of the organization to ensure standards are reached in the most efficient manner. The coordination would act as a clearinghouse for inventory status, activities, and needs for the unit, coordinate with inventory specialists of other units, develop and maintain catalogs of inventories and data element dictionaries, and track cost and effectiveness of each inventory.

Staffing—*Central unit*—To the extent possible, the central unit should be composed of specialists free from sectorial interests and with essential skills and tools (Bie and Lamp 1983). The makeup should encompass a wide range of interests and include energetic individuals and devoted professionals with a sense of strong commitment and continuity in the cause of statistics, ecology, and environment (Hennemuth and Patil 1983).

Field crews—Field crews are usually either temporarily hired teams provided through contracting or a permanent roving team.

Generally, roving inventory teams should be considered instead of temporary teams hired to take on a specific job because roving teams can provide technical expertise as well as continuity. Quality control should be better with a roving team, and there should be costs saved in training and ongoing operations. Travel costs will probably be greater, however (Whiting 1983).

If contract or temporarily hired crews are used, then contracts must be developed and monitored for compliance.

Inventory Scheduling

Proper scheduling is essential to the success of the inventory and can serve as an additional means for achieving integration and coordination among resource staffs.

The primary goal is to ensure that inventories are scheduled so that the information will be available when needed. This requires that the designers know the planning time schedule of the organization.

In addition, the designers must also be aware of the budgeting process and cycle. In some instances it may be necessary to start budgeting for an inventory 5 to 6 years before the inventory is to be implemented. An excellent discussion on scheduling inventory activities may be found in Larson (1984).

The organization's budgetary process can be used to encourage cooperation and consolidation of data collection activities among various resource functions. If lead time is short and budgets are limited, specialists are forced to work together (Sheehy 1984). A cost-accounting system should be developed to assist in project control.

Quality Control

Procedural errors or bias are minimized through quality control. This consists of monitoring or checking field operations while in progress to make certain errors in data collection are within acceptable percent error range.

Measurements and observations should be made as objectively as possible. Detailed instructions should be provided for each step of the inventory and for each measurement to ensure uniformity. A central authority should be provided in case procedural questions arise. The need to have well-organized, well-trained, qualified professional crews to do the actual fieldwork is of paramount importance. Examples of expected results and reports are also recommended to help the crews understand why the data are needed and how they will be used (Whiting 1983).

Field Manual—Development of clearly written procedural manuals that minimize subjective situations will enhance the goal of obtaining reliable information.

As a minimum, field manuals should include the following:

- The inventory objectives and the intended use of the data.

- Exact definitions of the variables to be measured.

- Sample location procedures.

- A list of the specific measurement techniques.

- Field checking procedures. If contracting is used, set up financial penalties of various amounts for each type of error. Specific items to field check include:
  (1) Reference point, initial point, map and photography locations, measurements, and documentations.
  (2) Plot and plot frame layout accuracies.
  (3) All mechanical measurement and ocular estimate procedures and results.
  (4) Data recording forms and retained specimens (e.g., plant material or soil samples) for proper labeling, coding accuracy, inconsistencies, legibility, neatness, and completeness.

Field Form Design—If possible, the field form (data recording sheet) should be designed specifically to accommodate both the inventory crews in the field and the data entry personnel. Computer systems people should be consulted in the design of the forms. Some blank spaces should be included on the form to allow crews to record unusual information.

Some inventory crews have had great success in utilizing calculatorlike hand-held recorders (Beltz and Keith 1981), thus bypassing the need for paper forms. The most frequently used method of recording, however, is still paper and pencil.

Data records will eventually be entered into a computer through some form of keyboarding: card punching, key-to-tape, key-to-disk, or direct input. If the design of the form can accommodate the keyboard operation, as well as provide a recording medium for the inventory crews, the copying process, which is costly and error prone, can be avoided. Thus, when it is known that data will be punched on cards, forms limited to 80 columns of information will be appropriate.

If the field forms will require some deskwork, such as looking up and recording data from tables, then it may be easier to ignore automated data entry processes and design a form precisely suited to fieldwork. However, this will increase labor costs. As much as possible, such situations should be minimized.

The following suggestions will minimize frustrations in the automated uses of the data:

a. Data records should be limited to 80 characters. It is true that there are new techniques available that allow greater record lengths, but many current conventions, particularly the electronic data transmission, still limit input records to 80 characters. If all items of a data set cannot be recorded in 80 columns, a multiple-record data case will be required.

b. Identifying information that will uniquely label all appropriate records forming the data case should appear in the same columns of all records, preferably the first columns of the record.

c. Each record within the data case should be numbered so as to facilitate ordering and identification of record contents.

d. Under no circumstances should it be assumed that two consecutive lines from the field form will automatically end up as consecutive automated records; identification fields and record numbers guarantee the computer's proper ordering of the data if it is disturbed.

Crew Performance—Crew performance may be improved by:

a. Providing adequate housing, salary, and reasonable working hours.

b. Training in aerial photography and imagery interpretation, measurement techniques, and recording procedures and testing to determine deficiencies prior to actual field sampling.

c. Building workers' confidence in their own and their crew's abilities.

d. Using a numerical rating system for evaluating crew performance. The numerical system allows comparison and stimulates competition between crews.

e. Providing completely staffed and highly competent quality check crews. The quality check crews should inspect most plots considered difficult to install and a portion of all other plots.

f. Providing instant feedback to the field crews on quality of work.

g. Assigning highly rated crews the responsibility for quality control work, then switching duties between control and production. When data quality checks indicate that the allowable errors are well within the prescribed limits, then quality control crews become production crews. Such crews should revert back to quality control occasionally.

h. Informing crews as to how data will be used. The crews should have a firm understanding of how their data will be used in a decisionmaking process and how errors in the data collection can affect those decisions.

i. Using a reward system for outstanding work.

If a plot day per crew is the normal production, the check crew can inspect four plots per week. This allows 1 day per week for retaining and incidental reports. At this rate, 20 percent of the field plots are checked. This rate is desirable for about the first 2 weeks of field inventory but should be reduced as the crews gain confidence and experience. The check rate should increase toward the end of the field season to offset the effects of crew boredom or burnout. For a field average, checking 1 plot in 10 will often hold technique errors to an acceptable level.

Inventory Plan

One of the most important steps in designing an inventory is to develop a comprehensive plan. Such a plan ensures that all facets of the inventory, including the data to be collected, financing and logistical support needed, and the compilation procedures are thought out before the inventory begins.

In writing the plan, some type of formal scoping process using simple charts with critical path analysis has many benefits in addition to the obvious benefit of activity schedules. The plan development process is a catalyst for brainstorming activities that may lead to uncovering problems and avoiding crisis situations.

The degree of complexity is determined by the inventory managers' need to communicate to upper and lower levels of management or to cooperators and to ensure that the inventory stays on schedule. A plan is a working tool only. Modifications to schedule and activities are permitted and encouraged as information becomes available. It is also a recordkeeping tool. Accomplishments, resources used, and dollars spent may be noted on the plan as the project progresses to document events and to assist future planning (Larson and others 1984).

Sample contents of an inventory plan, modified from Husch (1978), are as follows:

1. Purpose or objectives of inventory.
   a. Why inventory is required.
   b. How information will be utilized.
   c. Under what auspices or support inventory will be executed.
   d. Available information including past surveys, reports, maps, or photographs.

2. Description of area to be inventoried.
   a. Location.
   b. Site.
   c. Condition of terrain, accessibility, transport facilities.
   d. General description of land area.

3. Information required from the inventory.
   a. Expected results in tabular format with all headings, rows, and columns identified.
   b. Desired precision of results.
   c. Maps, mosaics, or other pictorial material desired, including scales and kind of information.

4. Inventory design.
   a. Funds available, estimates of time and costs for all phases of work.
   b. General description of methods to be used.
      (1) Remote sensing imagery including how imagery is obtained.
      (2) Complete tally or sampling methods for resource information.
      (3) Area estimation procedures.
      (4) Relationships to be used for expressing estimated quantities, such as volume tables.

5. Measurement procedures.
   a. Description of design for both imagery interpretation and fieldwork.
      (1) Size, shape, and distribution of sampling units for stand information.
      (2) Calculation of intensity of sampling to meet required precision.
      (3) Measurement procedures for other parameters such as area, growth, damage, and mortality.
      (4) Standardization of coding and procedures.
   b. Imagery interpretation procedures.
      (1) Detailed instructions on all techniques.
      (2) Staffing and description of duties.
      (3) Instruments.
      (4) Forms and recording of observations.
      (5) Quality control.
      (6) Data conversion and editing.
   c. Field organization.
      (1) Crew organization and description of duties.
      (2) Transportation procedures and directives.
      (3) Camping instructions.
      (4) Provisions for logistical support.
   d. Field procedures, including detailed procedures on:
      (1) Sampling unit location.
      (2) Establishment of sampling unit.
      (3) Measurements on sample unit.
      (4) Instruments and directives for use.
      (5) Resource and plot measurements.
      (6) Other field measurements such as vegetation growth and mortality, or soil and topographic conditions.
      (7) Design of forms and recordings of observations.
      (8) Quality control.
      (9) Data conversion and editing.

6. Compilation procedures.
   a. Detailed instructions on reduction of imagery interpretation and field measurements.
      (1) Formulas for estimates of totals and their sampling errors.
      (2) Relationships to be used for converting imagery or field measurements to desired expressions of quantity; e.g., imagery interpretation volume tables, individual tree volume tables, etc.
   b. Calculation and compilation methods.
      (1) Description of procedure (desk calculation, electronic computers, etc.).
      (2) Detailed description of all phases of calculation from raw data on original forms to final results (for electronic computation, description of inputs, program, and outputs).

7. Final report.
   a. Outline (note that the inventory plan, with some modifications, can serve as a basis for the final report).
   b. Estimated time for preparation.
   c. Responsibilities for preparation.
   d. Method of reproduction.
   e. Number of copies.
   f. Distribution.

8. Maintenance.
   a. Storage and retrieval of inventory data.
   b. Plans for updating the inventory.

Documentation

Throughout the whole inventory process, the need to document cannot be overemphasized. Documentation often provides the only mechanism for resolving differences that may occur in the integration and analyses processes.

Minimum documentation should consist of:

(1) The inventory plan, including inventory objectives, standardization maps, and imagery, sample design, sample size calculation, elements, definitions, measurement techniques, dates of inventory, and analysis procedures.

(2) The field manual.

(3) Maps and aerial photograph stereo (or other imagery used) pairs of each field location sampled. These are essential for relocation and remeasurement in subsequent inventories.

(4) Summary of the inventory, including degree of accomplishment, noting such items as field samples not measured or established, substitute samples, production rates, and unusual situations that affect inventory results or costs. A summary of inspection reports evaluating technique errors must be included.

(5) Tabular results of the inventories, including statements of attained sampling errors.

In addition, records should be kept in response to the following questions:

- How were the objectives of the inventory reached?

- How were analyses conducted to meet the objectives?

- What changes were made in the inventory and plan, and what were the reasons for those changes?

To the extent possible, all records should be kept at a central location under the supervision of a custodian or coordinator.

Data Use and Maintenance

After data are collected, they must be assembled into an information system. Most inventories require computers for storage and manipulation of the data. Wakeley (1983) recommends sharing a computer with the payroll and accounts receivable departments. A full-time programmer/analyst should be involved in the design of the system and with the processing of the data. Efficient use of computers systems in turn requires set codes and formats and forces the development of common data recording and retrieval elements (Schlieter 1981).

Editing the Data—Edit lists or ranges are generally developed before the inventory and are given to the crews for use in the field. Field editing of the data against the lists certifies that instructions were followed and values truly represent the items inventoried. A person other than the recorder should always check the field form for errors and omissions before leaving the plot.

A further step in process of automating the inventory data is the "desk check" of the field forms. Ideally, this audit of the recorded information is performed by personnel other than the recorder to help catch misunderstood definitions, limits, etc., and to certify legibility. This check need not be exhaustive, because a computerized check will catch most errors; however, a glance through the forms by qualified personnel will often catch errors before the data are entered into the computer. As the term implies, the desk check is best performed away from the field location to ensure a more unbiased audit. Most corrections, however, should be made by the persons who collect the data.

The step most frequently omitted in the process is the computerized validation in which data are screened for miscoding. Invalid values or combinations of values often appear during analyses and require correction and reprocessing of the data—"data cleaning." Such errors, if not detected, may invalidate the analytical results. In a recent national inventory, the error rate in data records varied from 5 percent to 98 percent. The 98-percent error rate resulted from entry of a consistently incorrect code on nearly all forms and would have seriously hampered analysis.

Computer edits should be started while crews are still in the field. Errors in data detected through the computer edit can be corrected by the crews going back to the plots to obtain the correct information.

Use and Analysis—Users need instructions for interpreting the data. They may misconstrue accuracies and levels of definitions and inappropriately extend the conclusions beyond the inventory design (Whiting 1983).

There are many commercial or general purpose packages of analytical software available that perform statistical summaries or analyses, for example, FINSYS (Born and Barnard 1983) and FIDAPS (Singh and Lanly 1981a). Generally, using existing software is more practical than designing one's own; it takes less time to actually get results and the probability of achieving statistically correct results is greater. The conventional 80-column input record will prove compatible with most commercial or general purpose packages.

Individual software packages, on the other hand, have advantages that may outweigh those of commercial packages. They may be easier to use because they are tailored to a specific use. Input to commercial packages is often difficult and may require the reformatting of data. Output from a specialized package is less verbose than that of generalized packages, and the format of the customized output may be designed to meet publication needs directly. Many statistical packages are primarily designed for analyzing survey data. Wilson, Schreuder, and Kent (1982) compare various survey sampling estimation packages.

An obvious compromise is the use of standard statistical library routines as the working portion of individual software packages. These libraries, available at most computer centers, provide sound statistical results, yet allow the user to control input and output. The choice of analysis package should be based on the available time and personnel, and the ultimate use of the output.

Criteria for evaluating existing software include:

- Will the program save the resource managers time and enable them to better manage the resource?

- What are the direct and indirect costs of operating the program?

- Can the program be used by people who are unfamiliar with computer operations, that is, is it menu-driven?

- Can the outputs be easily understood by the manager or landowner?

- Is it practical to operate the program from field locations, or would mail delays, communication problems, and special equipment limit its use?

- What equipment, facilities, and support are needed to operate the program?

- Is the program written in a standard programming language so that it can be operated with only minor adaptions on a wide range of makes and models of computers?

- Is the program small enough or so structured that it can be operated on business-oriented computers?

- Is documentation complete and usable?

- Can modifications be made by users who are not familiar with the program or resource problems?

Storage and Structure—Data should be retained for future use, comparisons, and monitoring change. Automated data base management systems provide outstanding capabilities for storage and quick retrievals. Such systems should be relatively simple, cheap, easy to use, and adaptable and should maximize local responsibility and control of data.

For large organizations, Case and others (1984) recommend that resource information be housed in a system of distributed data bases, a series of smaller data bases located at different sites. Standard definitions and programs allow data to be exchanged with minimum reformatting. A distributed system makes the best use of scarce computer resources. Because most transactions related to local inventory data involve small processes, data bases should be kept as small as possible and processed on local computers.

Because local users have the most critical need for information in the inventory, and thus the strongest interest in the accuracy, currency, integrity, and completeness of the data, responsibility for the maintenance and control of the data bases should be assigned to the lowest organizational levels of the agency.

The data base should be structured so that it provides management with information on demand in the format requested, rather than through fixed outputs (Wakeley 1983).

Murphy (1981) recommends the use of data bases consisting of only plot summary information for processing special requests. Data bases consisting of details collected for each tree or plant are not appropriate for processing unitwide summary reports nor are they cost efficient for creating intermediate files for use as input to application programs. Plot summary data bases also facilitate the exchange of inventory information between organizations and allow the merging of files in the case of multiorganization or multiresource inventories.

In addition, Case and others (1984) recommend relational data base architecture for integrated inventory systems. A relational data base is constructed using two dimensional tables of data that can be joined to form associations. These relational data bases are flexible so that the content and structure of the data base can be changed as information needs change. Inventories can be linked together as long as one item in each data base is held in common. Relational data base programs (software) are easy to learn and use.

If the data will be accessed only occasionally, storage costs may preclude the use of a data base. Off-line storage costs are low. Magnetic tape storage is probably the least expensive and most widely used form of storage. Off-line storage provides reasonably rapid access to data without the expense of on-line storage and the space requirements of hard copy storage. The greatest disadvantage of magnetic tape is the need to rewind it annually to prevent self-destruction.

Microfiche, including data processing documentation, provides a nonautomated, space-conserving method of data retention. Obviously, if machine processing is likely, this form of retention is undesirable. But for historical or verification purposes, it is very useful. Commercial facilities that convert automated data files to microfiche are available nationwide. Original field forms should be retained at least until the next inventory.

Transferring and Sharing Data—Transfer of data should be planned for before the inventory is implemented (Whiting 1983). For transferring data between computer systems, Alder (1980) recommends the use of 9-track magnetic computer tapes and ascertaining density (bits/inch), parity, and interblock gap in millimeters. Such information should be attached to the tape.

Tapes should always be character-encoded or formatted and should preferably use fixed-length records of moderate size (less than 120 characters/record) to facilitate reading the tape. The type of character-encoding used should be documented. A listing of the first and last few hundred lines of the tape should be sent along with the tape so that it can be checked for completeness.

Tapes can be sent through the mail, but they should be clearly marked so that high-frequency metal detectors will not erase them. The sender should maintain a spare backup tape. For additional information on resource data management see Moser (1976).

To set our from scratch to put together a completely integrated system of inventories as shown in figure 1 would be a formidable task to say the least. Usually integrated systems are developed by less ambitious means. For example, a group of resource specialists representing two or more organizations may get together to standardize their inventory procedures. They may believe that their current procedures are poor, or perhaps the results of the inventories are not comparable.

Regardless of the reason, if the group does develop a standardized procedure they then attempt to convince their respective organizations to adopt it. If it is adopted, then multilocation integration has taken place.

If one of the organizations has the responsibility of managing the resource for multiple uses, the standardized procedure could have a heavy influence on the design of any multiple resource inventories that may develop.

If the new standardized technique is used to feed several planning levels within the organization, multilevel integration also occurs. This integration could conceivably carry up to the national and international level (depending on the organization's mission) and thus influence other institutions both national and international not involved in the initial group of representatives.

Lastly, as use and adoption of the procedure expands, the inventories become linked over time. Thus, the entire spectrum of integration has occurred.

Unfortunately, the integration that has occurred may not have met all the needs of the various resources and organizations affected. All too often, when standardization and integration are first discussed, a far too narrow perspective is taken. All the potential impacts need to be identified and understood before standardization is proposed and adopted.

Integration is desirable only to the extent that it meets the need for which it is intended. Integrated inventories require sophisticated and costly designs and data processing systems. The amount of data to be generated and its uses govern the number of populations to be sampled. The number of products for which information is sought governs the number of measurements on each population sampled.

The more sophisticated and complex the system is, the more experienced the people involved need to be in obtaining the data. More people and time are then required to collect, process, and analyze the data (Breeman 1974). Unfortunately, the most limiting factor in designing and implementing integrated inventories is not technology but personnel and funding.

Nevertheless, integrated inventories in one form or another are becoming a reality and a necessity.

An integrated system of inventories can be considered adequate if it 1) fulfills the needs, objectives, and mission of the entire organization; 2) provides accurate, effective, and timely information on the present and potential conditions of the resources that are of concern; 3) results in improved decisionmaking and transfer of information at all the pertinent levels; 4) results in competitive returns on the investment in the system; 5) results in plans which are implementable; 6) can be understood by the users in the field; and 7) can be updated when unplanned changes in the resource base occur.

Systems should be designed rather than left to chance. Successful integrated systems are basically a function of common sense. In multiorganization inventories, it would be far more efficient to have one organization and perhaps one group or individual within that organization solely responsible for the entire inventory effort. This is not always possible because of the politics involved.

For multilevel inventories, information needs should be defined from the broadest level to the more specific. Data should then be collected at the lowest decision level and aggregated upward. Additional inventories may be needed at the more local levels for specific and immediate actions.

Multiresource designs should allow for different sampling intensities and sample selection in time and space; be able to accommodate poststratification; allow for efficient use of covariate information; minimize complexity in estimation; accommodate new statistical standards in estimation; allow for variability in design and estimation for variables in the same class; and allow information to be integrated with other available information.

In all probability most multiresource inventories will be extensions of existing inventories. Existing inventory costs may increase because of the costs of expanding the sampling frame onto land or vegetation types not previously covered, providing new training and increased supervision, collecting the new data at each sample location, and processing the new data (McClure 1980).

Resource staffs, such as timber or range, having inventories already in operation may have to carry the additional costs of expanding to meet the information needs of other resources. Cost includes the sampling unit layout, the localization system of sampling units, the data processing system, and the storage of data on numerous resource characteristics. Other information is obtained by additional sampling planned and carried out on the basis of the existing information systems.

Special-purpose and single-purpose inventories such as timber sale cruises still are useful and necessary particularly in planning project activities and actions. It is easy to get carried away by the enthusiasm over integration, but we hope common sense will prevail and remind us that integration is not always necessary. It would be foolhardy and wasteful, for example, to require measurement of the vegetation and soils in a given pasture if all we need to know is the number of sheep grazing it now. Data are expensive to collect, store, and analyze, and certain types of data require highly sophisticated equipment or highly specialized individuals for gathering and analysis. The resulting information may not justify the cost (McClure 1980).

When single purpose or separate inventories are necessary, they should be coordinated with other data collection efforts to avoid duplication of efforts. Responsibilities should be assigned specifying who will collect what, where, how, and when. Management objectives and needs of the survey should determine the standards and the requirements for multiresource inventories.

Monitoring optimally requires the establishment and remeasurement of permanent plots to best measure change and to predict trends. The capability for monitoring must be built into the first inventory; monitoring needs must be considered at the beginning of the planning process rather than at the end.

Monitoring to update some aspects of information bases can be accomplished with remote sensing or with information from a direct field inspection, as a means of updating and tracking changes in vegetation types or other mapped data (Navon and Oswald 1981).

Temporal integration is important for monitoring trends and developing reliable equations to predict the future supply of resources and changes in land use. To do this reliably requires uniformity of definitions, standardization in inventory procedures, and efficient sampling strategies. The same population of reference should be used throughout. Complete documentation of what is done is required. The proposed three-phase sampling with subsampling strategy should be efficient for assessments at a given point in time. For short-range monitoring computer simulation models may be used.

To monitor change at regular intervals over time, two primary options exist. One is to sample with partial replacement; that is, some new sample units replace some old sample units. The second is to sample with no replacement; that is, the original samples are resampled. The second option is favored, if it is politically feasible to do this in a scientifically acceptable manner.

Cooperation, coordination standardization, objectivity, and control are common threads for multilocation, multilevel, multiresource, and temporal inventories. Without these links, integration cannot occur nor should it be sought.

To meet the requirements of the Forest and Renewable Resources Planning Act of 1974, the National Forest Management Act of 1976, the Federal Land Policy and Management Act of 1976, and the Soil and Water Conservation Act of 1977, Federal agencies seek integration of inventory. To that end, agencies should coordinate all their inventory taking to reduce duplicate data collection and to increase the utility of their information. Such inventories should include a determination of the present potential of the land. The inventories should be based on statistically sound sample designs, use common definitions and standards, and assure consistency of information between planning levels. Existing information should be used where appropriate. Agencies should maintain and keep the inventory current and periodically evaluate the existing data for validity.

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